MAC Phase 4:

Marillana Creek Baseline Aquatic Ecosystem Survey

Dry 2020 & Wet 2021

Biologic Environmental Survey

Report to BHP Western Australia Iron Ore

March 2022

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GLOSSARY

ALA	Atlas of Living Australia
ALS	Australian Laboratory Services
BOM	Bureau of Meteorology
DBCA	Department of Biodiversity, Conservation and Attractions
DGV	Default Guideline Value
DO	Dissolved oxygen
DPIRD	Department of Primary Industry and Regional Development
DWER	Department of Water and Environmental Regulation
EC	Electrical conductivity
EPA	Western Australian Environmental Protection Authority
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
EWR	Ecological Water Requirements
GDE	Groundwater dependent ecosystem
GDV	Groundwater dependent vegetation
IDE	Inflow dependent ecosystem
IUCN	International Union for the Conservation of Nature
LWD	Large woody debris
MNES	Matters of National Environmental Significance
PBS	Pilbara Biological Survey
PEC	Priority Ecological Community
SRE	Short-range endemic
WAM	Western Australian Museum

EXECUTIVE SUMMARY

Biologic Environmental Survey (Biologic) was commissioned by BHP Western Australia Iron Ore (WAIO) to undertake a two-season baseline aquatic ecosystem survey of an upper reach of Marillana Creek (hereafter referred to as the Study Area), located within the Upper Fortescue River Catchment. Aquatic ecosystem surveys were undertaken at 12 sites, six within the Study Area, and six reference sites located outside the Study Area. Sampling was undertaken in September 2020 (dry 2020 survey) and April 2021 (wet 2021 survey). Surveys included habitat assessments and sampling of water quality, wetland flora (submerged and emergent macrophytes) and dominant riparian vegetation, zooplankton, hyporheos, macroinvertebrates and fish. Methods followed those used in similar surveys, including the Pilbara Biological Survey (PBS), National Monitoring River Health Initiative, and recent surveys undertaken by Biologic for other BHP projects nearby.

The Study Area lies within an open overstorey of *Eucalyptus camaldulensis*, *Melaleuca argentea* and *Melaleuca glomerata* over various *Acacia* species, with reeds and rushes along the waterline (*Cyperus vaginatus, Eleocharis geniculata*, *Schoenoplectus subulatus* and *Typha domingensis*). *Melaleuca bracteata*, *Cyperus ixiocarpus* and *Acacia ampliceps* were also present at some sites. Submerged macrophytes included *Naja tenuifolia*, *Vallisneria nana*, *Potamogeton tepperi*, *Potomogeton tricarinatus*, *Ruppia polycarpa*, *Chara* sp., and *Nitella* sp. The survey indicated that within-site richness of wetland flora (submerged and emergent macrophytes) was high. In particular, MarC4 and MarC6 were both found to have higher wetland flora richness than that recorded during the flora component of the PBS, including the Weeli Wolli Spring Priority 1 PEC site (as sampled prior to any impacts from mining or invasive species). Several phreatophytes and mesophytic/hydrophytic indicator species were present across the Study Area, indicating the presence of a number of Groundwater Dependant Ecosystems (GDEs) of varying levels of significance. These included:

- Marillana Creek – High significance GDE from the confluence of the tributary and Marillana Creek (i.e., MarC2), extending 2.4 km downstream to MarC4 (this GDE also extended 1.2 km up Marillana Creek, upstream of the confluence with the tributary).
- Marillana Creek – Lower significance GDE from MarC4 downstream 1.45 km to just below MarC5.
- Tributary – A small, isolated lower significance GDE extending for approximately 250 m and encompassing sampling site MarC1.

Water quality within the Study Area was characterised by fresh to brackish, well buffered, clear waters, with good dissolved oxygen saturation, slightly basic to circum-neutral pH, low nitrogen nutrient concentrations but high total phosphorus, and generally low dissolved metal concentrations. While water quality was generally within ANZG (2018) default guideline values (DGVs) for the protection of lowland river systems of tropical north Australia, there were some exceedances (i.e., dissolved oxygen, total nitrogen, dissolved boron, dissolved copper and dissolved iron, at some sites).

Several water quality characteristics indicated pools were maintained by both groundwater input and contribution by rainfall. Most sites were dominated by sodium (Na) cations and hydrogen carbonate (HCO_3) anions, with some exceptions (particularly at MarC1 and MarC6). Generally, there was a longitudinal decrease in Ca concentration along Marillana Creek. There was no evidence of evapoconcentration over the dry season as pools receded in the Study Area, with EC generally being higher in the wet season, unlike most creek pools in the Pilbara.

A diverse range of aquatic fauna was recorded across the Study Area, including 314 invertebrate taxa and two freshwater fish species. Generally, the Study Area supported high invertebrate taxa richness in surface waters and hyporheic zones, including a number of conservation significant and Pilbara endemic taxa. Three sites in particular (MarC2, MarC4 and MarC5), appeared to be of considerable ecological value for invertebrate fauna.

Within the hyporheos, a total of 11% of taxa recorded are directly dependant on groundwater for persistence (8% stygobites and 3% permanent hyporheos stygophiles). The percentage of stygobitic taxa was greater than that reported previously for Pilbara hyporheic zones (i.e., 5% stygobitic fauna recorded in Halse *et al*. 2002), highlighting the connection with groundwaters in this reach of Marillana Creek. Greatest richness of groundwater dependent taxa (stygobites and permanent hyporheos stygophiles only) across all sites (including reference sites) was recorded from MarC2 in the dry 2020, and reference site SS in the wet 2021, closely followed by MarC4. This re-enforces the evidence for strong groundwater connection within Marillana Creek, particularly at these sites.

Macroinvertebrate richness was generally high throughout the Study Area, especially at MarC2 and MarC5. When compared statistically to previous aquatic surveys undertaken in the area, macroinvertebrate richness from the Study Area was statistically similar to all other creeklines/ reaches included in the analysis, including the Weeli Wolli Spring PEC (as sampled during the PBS prior to any disturbance or mining impact), and the Davis River (also known for its high richness of aquatic fauna) (Kendrick & McKenzie, 2001). Also of particular note within the Study Area, was the exceptionally high richness of odonates at MarC5 (14 taxa in the dry) and MarC6 (11 taxa in the wet). The high richness of odonates likely reflects the fact that the Study Area supports good, intact riparian vegetation and a high abundance and diversity of submerged and macrophytes.

While most invertebrates recorded from the Study Area were common, ubiquitous species, several species were of conservation significance and/or appear to be restricted or are known from few records. Such taxa include:

- the stygal ostracod *Gomphodella alexanderi* (MarC2) - known only from Marillana Creek, groundwater bores at Yandi, Yandicoogina Creek, and lower Weeli Wolli Creek.
- *Bennelongia* `sp. Biologic-OSTR026 (MarC1) - currently known only from Marillana Creek, but further work is required to confirm this.

- Cyprididae `sp. Biologic-OSTR014` (MarC3, MarC4 and MarC6) – currently known from two locations; Marillana Creek and the Angelo River Project Area (approximately 70 km to the south of the current Study Area).
- Cyprididae `sp. Biologic-OSTR015` (MarC1) – currently known from two locations; Marillana Creek and the Angelo River Project Area.
- Cyprididae `sp. Biologic-OSTR019` (MarC5 and MarC6) – known only from the Study Area and the Angelo River Project Area, based on current information.

- The Pilbara pin damselfly *Eurysticta coolawanyah* (MarC5) - Vulnerable on the IUCN Redlist. Also recorded from reference sites MACREF2, MACREF1, WWS, BENS and SS during the current study.
- The Pilbara emerald, *Hemicordulia koomina* (MarC1, MarC4, MarC5 and MarC6) - Vulnerable on the IUCN Redlist. Also recorded from reference site BENS.
- The water mite *Aspidiobates pilbara* (MarC2 and MarC3) – Pilbara endemic known only from springs and permanent pools in good ecological condition.
- The beetle *Haliplus fortescueensis* (MarC4) – Pilbara endemic with its main area of occurrence restricted to the Fortescue Marsh region.

Other potentially restricted taxa for which species distributions could not be resolved due to insufficient information and/or a lack of suitable keys were also recorded (complete list provided in Table 6.1).

Due to the aridity of the Pilbara, rivers of the region tend to be ephemeral. As such, permanent water sources in the region are relatively scarce and restricted to springs and permanent pools. Three sites within the Study Area were considered to be of high ecological value due to the high richness of wetland flora, diversity of mesophytic/ hydrophytic indicator species, and high richness of invertebrate taxa, including restricted species and those listed on the IUCN Redlist. Permanent springs in shaded gorges and riverbeds support a suite of mesic-adapted species that are otherwise rare in the region. As such, the stretch of Marillana Creek encompassing the Study Area would be considered to hold high ecological importance in the Pilbara region. The three sites that were found to hold considerable ecological value were:

1. **MarC2** which recorded a high diversity of GDV species, a relatively high richness of groundwater dependent invertebrate taxa (stygobites and permanent hyporheos stygophiles), conservation significant stygobitic species, taxa restricted to springs and permanent pools of high ecological condition, and overall high macroinvertebrate taxa richness.
2. **MarC4** which recorded a high diversity of GDV species, high richness of wetland flora (submerged and emergent macrophytes) in comparison to other creeks in the region, a relatively high richness of groundwater dependent invertebrate taxa, restricted species and IUCN listed species.

3. **MarC5** which recorded high overall macroinvertebrate richness, high richness of odonate species, including IUCN listed species, and a high richness of Pilbara endemic taxa.

For riverine pools to be termed GDEs they must have demonstrated long-term connectivity to the groundwater and be maintained by groundwater discharge during drought periods. GDEs support a unique suite of species and natural ecological processes that are dependent on the permanent or temporary presence of groundwater (Murray *et al.*, 2003). A number of physical and ecological elements highlight the close connection to groundwaters within the Study Area. These include:

- the presence of GDVs, including high-level mesophytic/ hydrophytic indicators such as *Melaleuca argentea, Eucalyptus camaldulensis*, *Acacia ampliceps* and *Melaleuca bracteata* and moderate-level indicator species species *Cyperus vaginatus*, *Eleocharis geniculata* and *Schenoplectus subulatus* (based on persistence mapping work) (Rio Tinto, 2021);
- the lack of any evapoconcentration or increased EC concentrations in the dry season;
- ionic composition dominated by carbonate anions, similar to other spring systems of the Pilbara; and
- the presence of stygofauna within the hyporheic zone.

1. INTRODUCTION

1.1 Background and objectives

Biologic Environmental Survey (Biologic) was commissioned by BHP Western Australia Iron Ore (WAIO) to undertake a two-season baseline aquatic ecosystem survey for the Mining Area C (MAC) Phase 4 Project. A reach within Marillana Creek, located upstream of BHP WAIO Yandi operations on non-BHP WAIO tenure, was targeted for survey (hereafter referred to as the Study Area; Figure 1.1). The Study Area is located north of the current BHP WAIO MAC operation, within the East Pilbara region of Western Australia. The overarching objective of the two-season survey was to identify the aquatic fauna found in perennial and semi-permanent pools associated with the target reach of Marillana Creek, and to determine the associated ecological values of aquatic fauna and habitats that may need to be considered during any future environmental approvals across the area.

The scope of works included:

- A desktop assessment, including a review of previous biological surveys and government and non-government databases;
- Identification of appropriate sampling locations along Marillana Creek (permanent and semi-permanent pools), as well as suitable reference sites outside the Study Area;
- A baseline aquatic survey within the Study Area and reference pools; and
- Identification of any significant ecological values related to aquatic fauna and habitats associated with these pools.

1.2 Legislation and guidance

The survey was carried out in accordance with the Western Australian Environmental Protection Authority (EPA) and BHP WAIO guidelines. There is currently (June 2021) no technical guidance applicable to the Inland Waters Environmental Factor; however, this survey was carried out in a manner consistent with the following:

- Environmental Factor Guideline, Inland Waters (EPA, 2018a).
- Technical Guidance, Sampling of Short-Range Endemic Invertebrate Fauna (EPA, 2016a).
- Technical Guidance, Terrestrial Fauna Surveys (EPA, 2016b).
- Australian & New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018).
- Similar surveys, including the Pilbara Biological Survey (Pinder *et al.*, 2010), National Monitoring River Health Initiative (Choy & Thompson, 1995), and recent surveys undertaken by Biologic for other BHP projects nearby (Biologic, 2020b, 2020d).
- BHP WAIO's Aquatic Fauna Assessment Methods Procedure (0098594) (BHP, 2020).

Legend

- Study Area
- Current BHP Tenure
- Mines
- State Road
- Major Creeks

IBRA Subregion

- Fortescue
- Hamersley

N

biologic Environmental Survey

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0 5 10 Km

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Projection: Transverse Mercator
Datum: GDA 1994 Created 18/02/2022

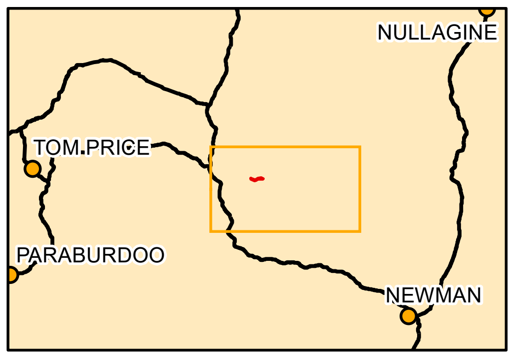

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Figure 1.1: Study Area and regional location

2 ENVIRONMENT

2.1 Biogeographical Regionalisation of Australia

The Study Area falls within the Pilbara biogeographical region as defined by the Interim Biogeographic Regionalisation of Australia (IBRA) (Thackway & Cresswell, 1995). The Pilbara bioregion is characterised by vast coastal plains and inland mountain ranges with cliffs and deep gorges (Thackway & Cresswell, 1995). Vegetation is predominantly mulga low woodlands or snappy gum over bunch and hummock grasses (Bastin, 2008).

The Pilbara bioregion is classified into four separate subregions, Chichester (PIL01), Fortescue (PIL02), Hamersley (PIL03) and Roebourne (PIL04), of which the Study Area is located within the Hamersley subregion (Figure 1.1). This subregion contains the southern section of the Pilbara Craton and comprises a mountainous area of Proterozoic sedimentary ranges and plateaux, dissected by basalt, shale and dolerite gorges (Kendrick, 2001). The Hamersley contains extensive open snappy gum woodland and hummock grassland communities on ranges and plateaus, with low mulga woodlands over bunch grasses on fine textured soils in lower areas and valley floors (Kendrick, 2001).

The significant and dominant feature of this subregion is the Hamersley Range. This prominent range feature is a mountainous plateau, some 450 km in length, which receives considerably higher rainfall than the surrounding subregion. The plateau is dissected by deeply incised gorges, containing extensive permanent spring-fed streams and pools (Kendrick, 2001). Drainage is into the Fortescue River to the north, the Ashburton River to the south, or the Robe River to the west.

2.2 Hydrology

MAC is mostly located within the Weeli Wolli Spring catchment, with northern parts of the mining lease extending over the catchment divide into the Yandicoogina Creek catchment. The current study focussed on Marillana Creek, as it is an option for discharge of excess groundwater.

Marillana Creek comprises a major tributary of Weeli Wolli Creek (Figure 2.1). The Marillana Creek catchment covers an area of approximately 2,050 km^2 (Johnson & Wright, 2001). Its headwaters rise from the Hamersley Range, and flow in an east and north-easterly direction into the Munjina Claypan (Rio Tinto, 2012). When the internal holding capacity of the claypan is exceeded, surface water flows south-east into the lower Marillana Creek catchment (Rio Tinto, 2012). The upper catchment is characterised by a broad alluvial plain with large areas of calcrete, while lower in the catchment, in the vicinity of the Study Area, the drainage is well defined (Johnson & Wright, 2001). Marillana Creek is known to support several permanent and semi-permanent pools along its length naturally, including one named pool (Flat Rocks). This pool is located within the Study Area, upstream of current BHP and Rio Tinto mining operations. Several tributaries contribute flows to Marillana Creek, including Lamb Creek, Phil's Creek, Yandicoogina Creek and many smaller, un-named creeks (Figure 2.1).

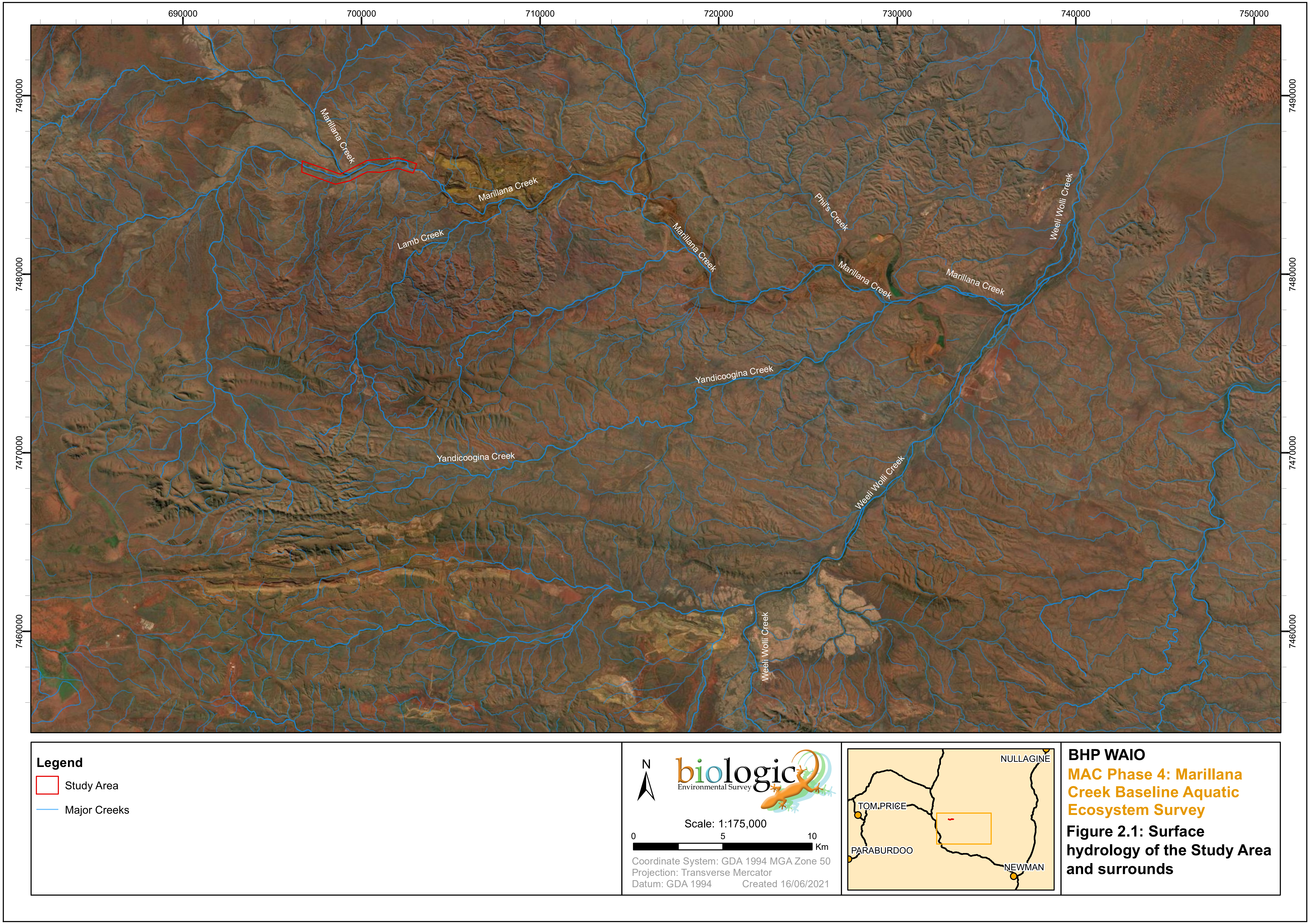

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Figure 2.1: Surface hydrology of the Study Area and surrounds

Marillana Creek flows into Weeli Wolli Creek, 40 km downstream of the Study Area. Weeli Wolli Creek has a catchment area of 4100 km^2 and is approximately 70 km long. It flows to the north, where it drains into the Fortescue River via the ecologically significant Fortescue Marsh (Figure 2.1). The two systems are only connected during flooding associated with intense cyclonic events (Kendrick, 2001). The Marsh lies approximately 80 km downstream, and to the north, of Marillana Creek (Figure 2.1). The Fortescue Marsh is a wetland system of national importance under the Directory of Important Wetlands in Australia (Environment Australia, 2001).

2.3 Groundwater Dependent Ecosystems

Groundwater-Dependent Ecosystems (or GDEs) are ecosystems that rely upon groundwater for their continued existence (BoM, 2021). GDEs can be represented by many different assemblages of biota which rely on groundwater, and as a result come in many forms. For terrestrial ecosystems there are three key types of GDE:

1. Aquatic ecosystems: that rely on the surface expression of groundwater – this includes surface water ecosystems which may have a groundwater component, such as rivers, wetlands and springs;
2. Terrestrial ecosystems: that rely on the subsurface presence of groundwater–this includes all vegetation ecosystems or Groundwater Dependent Vegetation (GDV); and
3. Subterranean ecosystems: this includes cave and aquifer ecosystems (BoM, 2021).

Above-ground terrestrial GDEs are typically characterised by the presence of flora species that rely on groundwater (i.e., phreatophytes). Phreatophytes may be classified as either obligate or facultative phreatophytes depending on their reliance on groundwater:

- Obligate phreatophytes are flora species confined to habitats with access to groundwater.
- Facultative phreatophytes are flora species that can utilise groundwater to satisfy a proportion of their ecological water requirement (EWR) when it is available. However, some individuals may also satisfy their EWR by relying solely on uptake from upper unsaturated soils layers where groundwater is inaccessible (Eamus *et al.*, 2016).

A national dataset of Australian GDEs was developed by the Bureau of Meteorology (BoM) to inform groundwater planning and management (BoM, 2021). This dataset is referred to as the Groundwater Dependent Ecosystems Atlas (GDE Atlas) and is the first and only national inventory of GDEs in Australia. The GDE Atlas contains information about the three key types of ecosystems described above (Aquatic; Terrestrial; and Subterranean). Importantly, the GDE Atlas also includes the national inflow-dependent landscapes layer which is derived from remotely sensed data. This layer indicates the likelihood that a landscape is accessing water in addition to rainfall (such as soil moisture, surface water or groundwater), and generally represents a potential GDE dataset for all areas not yet studied or investigated in any detail.

Mapping in the GDE Atlas comes from two broad sources:

- National assessment – national-scale analysis based on a set of rules that describe potential for groundwater/ ecosystem interaction and available GIS data.
- Regional studies – more detailed analysis undertaken by various State and regional agencies using a range of different approaches including field work, analysis of satellite imagery and application of rules/conceptual models.

The GDE Atlas indicates that the Marillana Creek Study Area has moderate potential to support GDEs based on the terrestrial and inflow dependent ecosystem (IDE) assessment (IDE likelihood classification of 9). However, no specific aquatic GDEs were highlighted within the Study Area in the GDE Atlas. Interestingly, Weeli Wolli Creek, which is a known terrestrial and aquatic GDE, is only classified as having a moderate potential to support GDEs. This may be a function of the national-scale analysis which follows a specific set of rules (Doody *et al.*, 2017). The national-scale GDE Atlas is an initial remotely-sensed task of the overall project, with follow-up surveys and investigations required to ground-truth the Atlas and identify the presence of any actual GDEs.

2.4 Climate

The Pilbara region has a semi-desert to tropical climate, with relatively dry winters and hot summers. Rainfall is highly variable and mostly occurs during the summer. It tends to be associated with convective thunderstorms, low pressure systems and tropical cyclones that generate ephemeral flows and occasional flooding in creeks and rivers (Leighton, 2004). Winter rainfall is generally lighter and the result of cold fronts moving north-easterly across the state (Leighton, 2004). Due to the nature of cyclonic events and thunderstorms, total annual rainfall in the region is highly unpredictable and individual storms can contribute several hundred millimetres of rain at one time. The average annual rainfall over the broader Pilbara area ranges from 200 to 400 millimetres (mm), although rainfall may vary widely from year to year (van Etten, 2009). Nearby rainfall gauging stations (GS) for the Study Area include the Department of Water and Environmental Regulation (DWER) Marillana Creek - Flat Rocks (#505011; length of record 1988 to current), located within the Study Area in close proximity to Biologic's current sampling site MarC6, and the DWER Marillana Creek - Munjina Station (#505004; length of record 1985 to current), located approximately 20 km west of the Study Area. Long-term average annual rainfall ranged from 410 mm at Flat Rocks to 435 mm at Munjina (DWER, 2021). Temperatures vary considerably throughout the year with average maximum summer temperatures reaching 35 °C to 40 °C and winter temperatures generally fluctuating between 22 °C and 30 °C.

3 METHODS

3.1 Desktop assessment

A desktop assessment was undertaken comprising database searches and a literature review. The purpose of the desktop assessment was to determine the extent of any previous aquatic survey work in and around the Study Area, and the presence of aquatic fauna species known or likely to occur in the area, including conservation significant species.

3.1.1 Database searches

Six databases were searched for aquatic fauna records within and surrounding the Study Area (Table 3.1).

Table 3.1: Databases searched for the review of previous records.

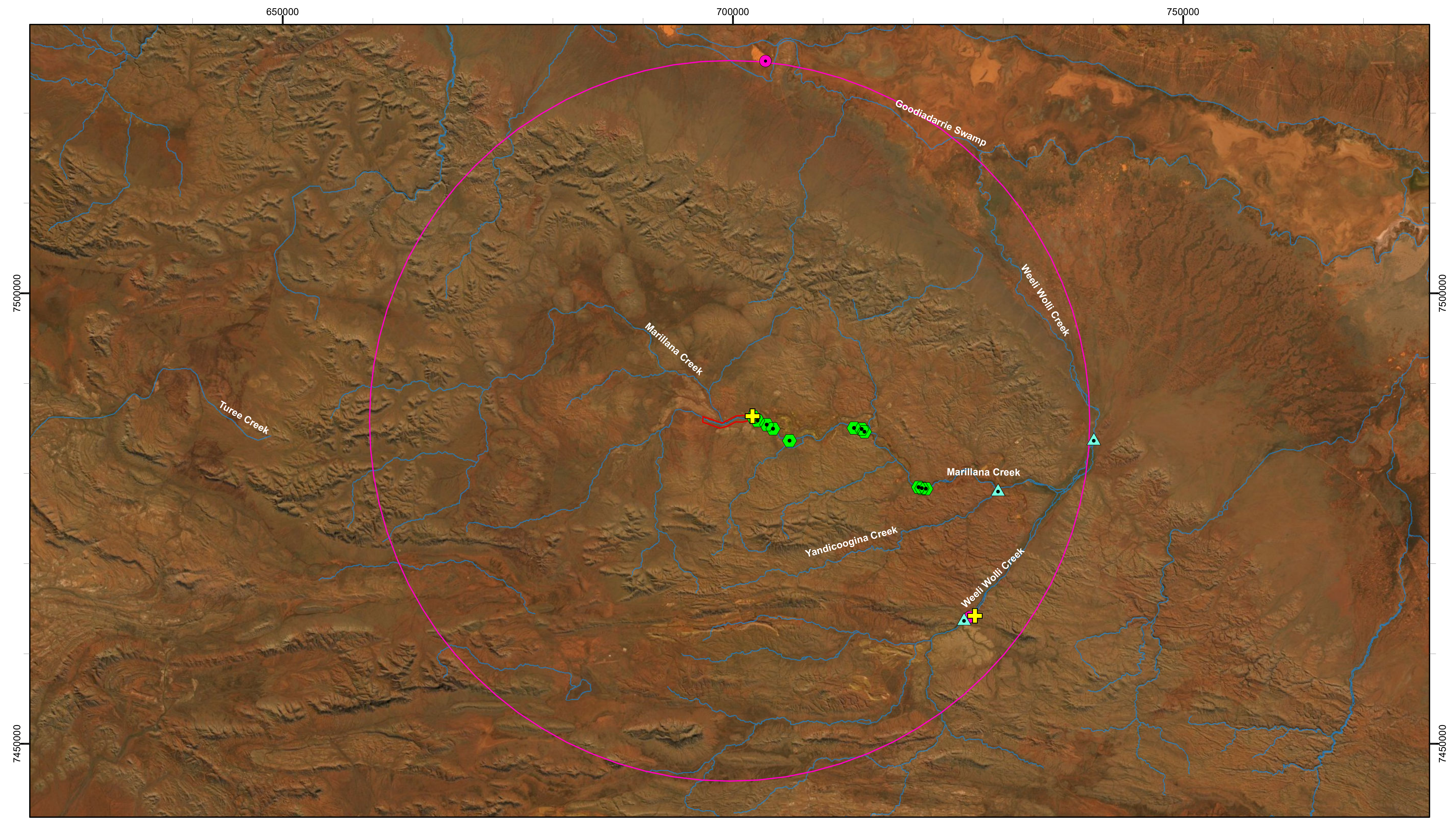
Provider	Database	Reference	Search parameters
Department of Biodiversity, Conservation and Attractions (DBCA)	NatureMap	(DBCA, 2020)	40 km radius centred on the coordinates: -22.722786° 118.943872°
Environment Protection and Biodiversity Conservation (EPBC)	Protected Matters Report	(DoEE, 2020)	
Atlas of Living Australia (ALA)	Species Occurrence	(ALA, 2020)	
Western Australian Museum (WAM)	Arachnids and Myriapods	(WAM, 2020a)	
WAM	Crustaceans	(WAM, 2020b)	
WAM	Molluscs	(WAM, 2020c)	

Other data sources referenced for this desktop assessment included:

- The Australian Faunal Directory,
- The Australian National Insect Collection Database; and
- MRHI database.

3.1.2 Literature review

A review of available literature relevant to the Study Area was undertaken to compile a list of aquatic fauna species previously known to occur nearby, and which therefore have the potential to occur within the Study Area. A number of surveys have included aquatic ecosystem sampling along Marillana Creek, with one site located within the Study Area (i.e., Flat Rocks, site MarC6 in the current study;Table 3.2 and Figure 3.1).Two of the reference sites utilised in the current survey were within 40 km of the Study Area and located at, or within the vicinity of, previous survey sites (i.e., Ben's Oasis and Weeli Wolli Spring).



Legend

Study Area

40 km Database Search Radius

Major Creeks

Previous Aquatic Surveys

Masini (1988)

Pinder et al. (2010)

Streamtec (2004)

WRM (2015 & 2018)

N

biologic Environmental Survey

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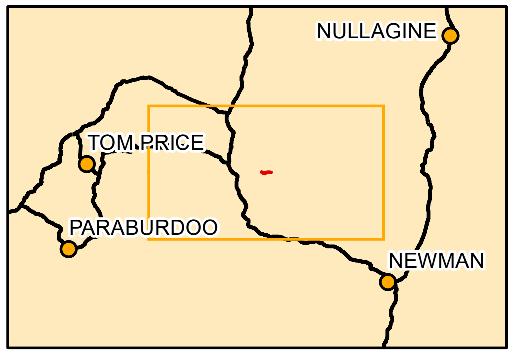

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Figure 3.1: Previous aquatic surveys conducted within 40 km of the Study Area

Table 3.2: Literature sources used for the review.

Survey Title	Reference	Survey Type	Closest Site to Study Area (km)
Inland Waters of the Pilbara	(Masini, 1988)	Water Quality, Aquatic Flora, Waterbirds & Fish	27 km (Sites 24 and 25; Junction: Marillana and Yandicoogina)
Aquatic Ecosystems of the Upper Fortescue River Catchment	(Streamtec, 2004)	Water Quality, Macroinvertebrates & Fish	Within Study Area (Flat Rocks)
Pilbara Biological Survey	(Pinder *et al.*, 2010)	Aquatic Flora, Zooplankton & Macroinvertebrates	33 km (Pilbara Biological Survey PSW026 at Weeli Wolli Spring)
Yandi: Marillana Creek Aquatic Fauna Survey	(WRM, 2015)	Water Quality, Zooplankton, Macroinvertebrates & Fish	Within Study Area (Flat Rocks and Flat Rocks Downstream)
Yandi: Marillana Creek Aquatic Fauna Survey	(WRM, 2018)	Water Quality, Zooplankton, Macroinvertebrates & Fish	0.87 km (Site MC1)

3.2 Field survey

3.2.1 Survey team

Field surveys were conducted by Biologic aquatic ecologists Jessica Delaney (Principal Zoologist | Manager of Aquatic Ecology), Kim Nguyen and Alex Riemer (Senior Zoologists | Aquatic Ecologists); all with extensive experience undertaking aquatic ecosystem surveys throughout the Pilbara region of Western Australia. Morgan Lythe (Senior Zoologist) and Siobhan Paget (Graduate Aquatic Ecologist) also provided assistance in the field during the wet season survey.

Fauna sampling was conducted under DBCA Fauna Taking (Biological Assessment Regulation 27) Licence BA27000290, and Department of Primary Industries and Resource Development (DPIRD) Instrument of Exemption to the *Fish Resources Management Act 1994 Section 7 (2)* number: 3266, both issued to Jessica Delaney. Flora was collected under DBCA Flora Taking (Biological Assessment) Licence FB62000095, issued to Jessica Delaney.

Macroinvertebrate specimens were identified in-house by Alex Riemer, Kim Nguyen, Juliana Pile Arnold, Giulia Perina and Morgan Lythe, with assistance from Jane McRae for the dry 2020 season samples (Bennelongia Environmental Consultants) for specific groups, such as Cladocera, Copepoda and Ostracoda specimens from hyporheic samples. Flora samples (submerged and emergent macrophytes) were identified by Biologic's Flora Team, including Samuel Coultas, Kaylin Geelhoed and Clinton van den Bergh, in conjunction with Alex Riemer and Morgan Lythe. Zooplankton samples were processed and identified by Dr Robert Walsh (Australian Water Life).

3.2.2 Survey timing, weather, and river conditions

The field survey comprised two sampling events. The dry season survey (Phase 1; hereafter referred to as dry 2020) was undertaken between the 31st of August and 3rd of September 2020, at a time of above average ambient temperature. Average maximum temperature (33.3°C) for September 2020 was 2.7 °C hotter than the September long-term average of 30.6 °C. Although limited rainfall occurs between May and September in the Pilbara generally, rainfall over these months at the Newman Airport gauging station (GS) was notably lower than the long-term average (Figure 3.2).

The wet season survey (Phase 2; wet 2021) was undertaken between the 17th and 20th of April 2021, when average maximum daytime temperatures (32.1 °C) were similar to the April long-term average temperature (32.2 °C). An active tropical low pressure system (12U) at the start of February 2021 resulted in above average rainfall across much of the state, with Newman Airport GS recording more than double the long-term average rainfall for that month (Figure 3.2). This was followed another cyclone in April 2021, which also led to above average rainfall at Newman Airport GS. The Flat Rocks GS on Marillana Creek also reported high rainfall for the 2021 wet season (DWER, 2021). February 2021 totals were well above the long-term average for the month (152.8 mm recorded in comparison to the average of 90.6 mm). However, conditions from previous years were very dry, with annual rainfall in 2018 (354 mm) and 2019 (289 mm) being well below the long-term average of 410 mm (DWER, 2021).

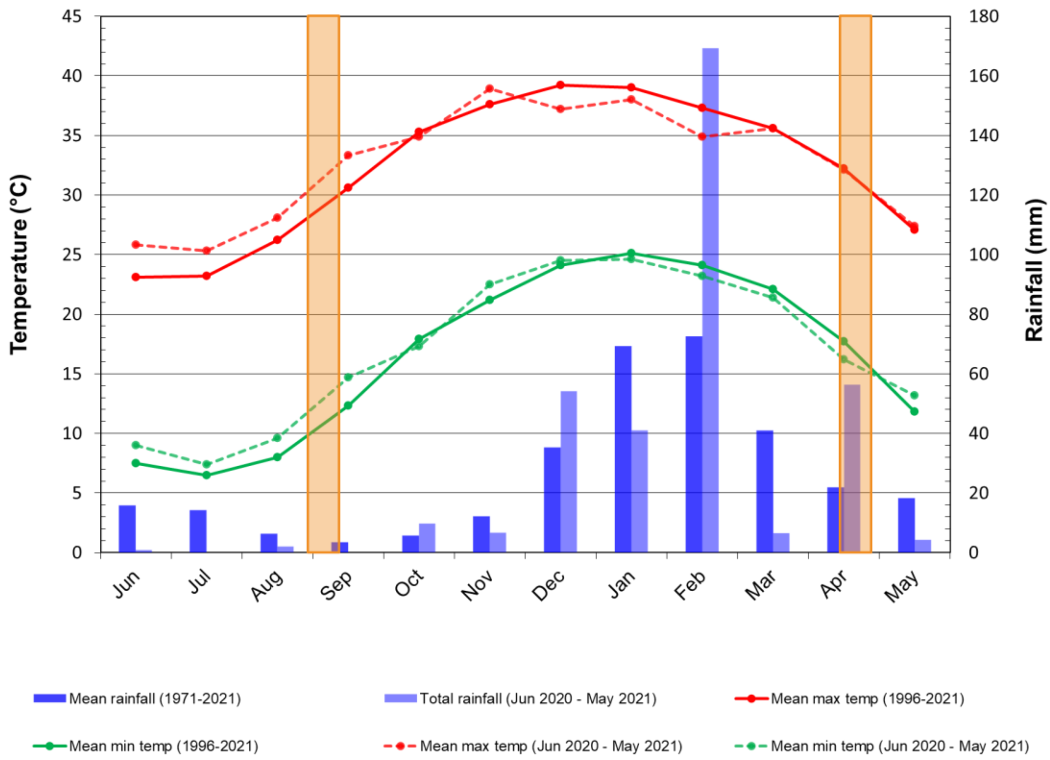


Figure 3.2: Total and long-term average monthly temperature (°C) and rainfall (mm) recorded from the Newman BoM gauging station in the months preceding the Marillana Creek baseline aquatic surveys. Orange bars indicate dry and wet season survey timing.

Long term average annual streamflow recorded from Flat Rocks GS (streamflow station number 708001) is 6995.97 ML. Monthly flows are typically highest in January and February, before receding over the course of the year (Figure 3.3). Streamflow in the Pilbara occurs as a direct response to rainfall. This is evident by the high flows and extensive flooding experienced at the nearby Waterloo GS (# 708013) in February and April 2021 (Figure 3.3), when low pressure and cyclonic activity brought heavy rain to the area. Unfortunately, no data were available for Flat Rocks, within the Study Area, from early February 2021, presumably because the streamflow gauging station was damaged during the flood. Therefore, the nearby Waterloo GS station data has been referenced for this period to show the influence of the low pressure system and cyclone on streamflows, with a total of 4,938 ML recorded for the month of April 2021, in comparison to the long-term average of only 1,515 ML (Figure 3.3).

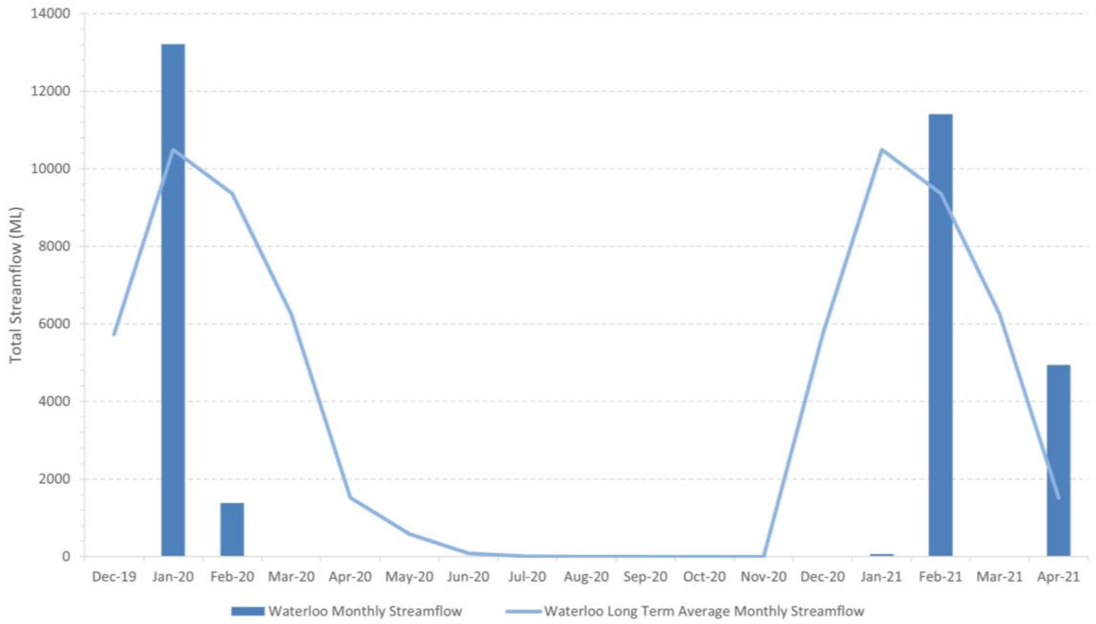


Figure 3.3: Monthly streamflow (ML) data at the DWER Waterloo GS on Marillana Creek, including monthly totals between Dec-19 and Jan-21 and long-term averages (1984-2020).

Figure 3.4 further illustrates the relationship between rainfall and streamflow, with high flows occurring during high rainfall years. Rainfall and flows have been considerably lower since 2000, in comparison to the previous 12-year period (Figure 3.4).

The consecutive tropical lows and cyclone in the wet season of 2021 resulted in widespread flooding across the East Pilbara, including within the Study Area. In the field, it was noted that the Davis River (Running Waters reference site) was still in flood at the time of the wet 2021 survey, with high bank full flows and turbid water present. All other sites were flushed and pools were full.

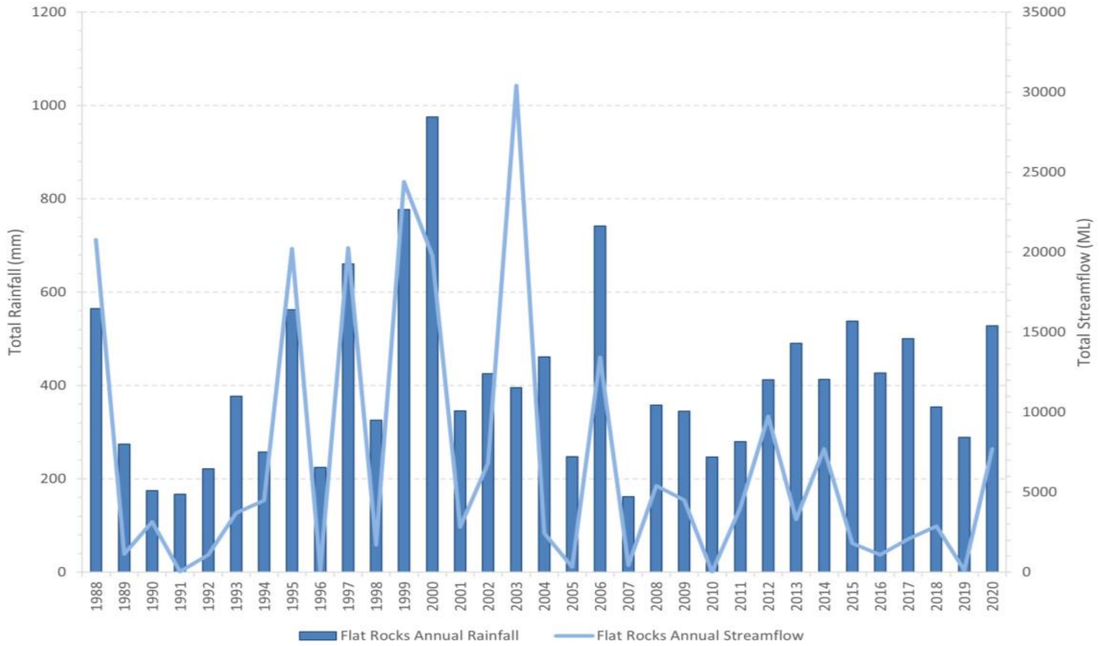


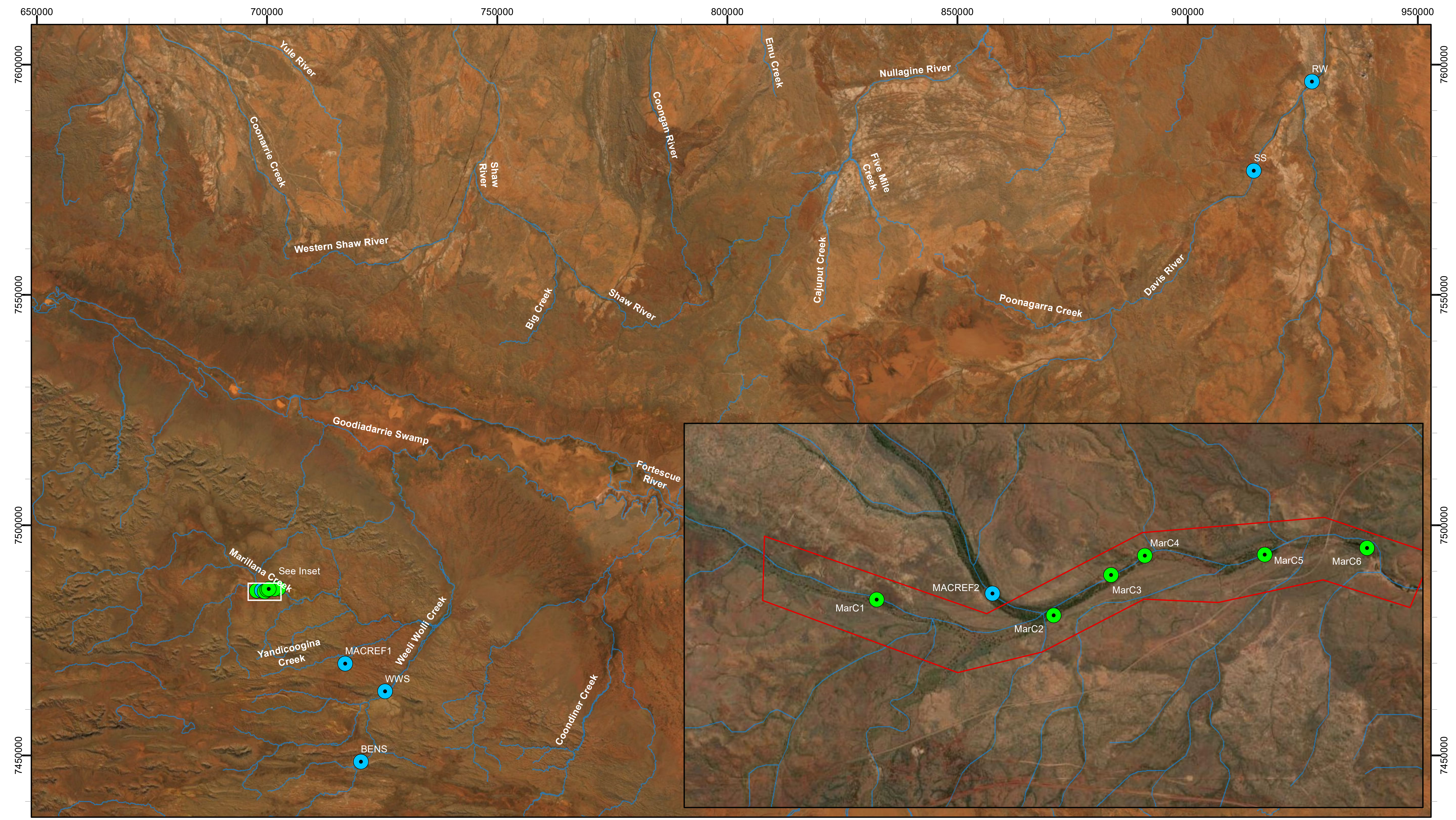
Figure 3.4: Annual rainfall (mm) and streamflow (ML) at the DWER Flat Rocks GS on Marillana Creek.

3.2.3 Sampling sites

A total of 12 sites were sampled in both seasons; six sites within the Study Area, and six reference sites. One reference site was located just outside the Study Area, on Marillana Creek, upstream of the confluence with the un-named tributary. All other reference sites were located on creeks and systems well outside the Study Area. The aim of reference site selection was to choose sites most similar to Marillana Creek, with respect to hydrology, persistence, morphology, and riparian vegetation, as well as being relatively close by and within the same climatic area. This is a difficult task in the Pilbara, a semi-arid region with few permanent pools and GDE systems present. The six reference sites included MACREF1 (located on a tributary of Yandicoogina Creek), MACREF2 (located on Marillana Creek, upstream of the confluence with the un-named tributary), Ben's Oasis and Weeli Wolli Spring (both located on Weeli Wolli Creek), and Skull Spring and Running Waters (both on the Davis River). Sample site information is provided in Table 3.3 and locations in in

Table 3.3: Site details, indicating site type and sampling effort. NB: D refers to dry season sampling (dry) and W refers to wet season sampling (wet). WQ = water quality, Zoop = zooplankton, Macro = macroinvertebrates and Hypo = hyporheic fauna.

					Sampling undertaken													
					Habitat		WQ		Flora		Zoop		Macro		Hypo		Fish	
Area	**Site**	**Latitude**	**Longitude**	**Type**	**D**	**W**	**D**	**W**	**D**	**W**	**D**	**W**	**D**	**W**	**D**	**W**	**D**	**W**
Marillana Creek	MarC1	-22.7242	118.9254	Within Study Area	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	MarC2	-22.7258	118.9421		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	MarC3	-22.7219	118.9471		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	MarC4	-22.7201	118.9505		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	MarC5	-22.7198	118.9618		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	MarC6	-22.7188	118.9704		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓
	MACREF2	-22.7235	118.9363	Reference	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Tibutary of Yandicoogina Creek	MACREF1	-22.8647	119.1145	Reference	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓
Weeli Wolli Creek	WWS	-22.9181	119.1994	Reference	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	BENS	-23.0558	119.1509		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Davis River	SS	-21.86	121.0114	Reference	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	RW	-21.6863	121.1248		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
			Total no. of samples		**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**10**	**11**	**12**	**12**



Legend

Study Area | Study Area Sites

Major Creeks | Reference Sites

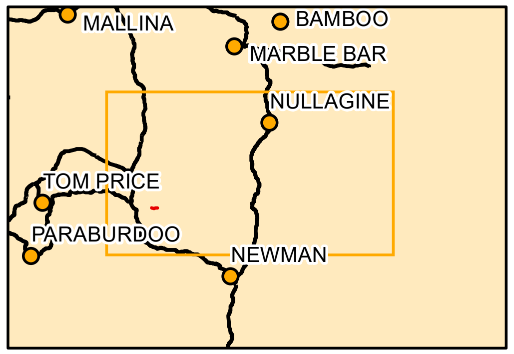
N

biologic Environmental Survey

Scale: 1:760,000

0 10 20 30 40 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 18/02/2022



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 3.5: Aquatic ecosystem sampling sites

A brief description of each site is provided below:

Study Area Sites

- Tributary of Marillana Creek (MarC1): One pool located on a tributary which flows into Marillana Creek, downstream of the potential discharge location.
- Marillana Creek: Five pools (MarC2, MarC3, MarC4, MarC5 and MarC6), located downstream of the confluence with the un-named tributary.

Reference Sites

- MAC Reference 1 (MACREF1): permanent pools and riffle sequences located on Yandicoogina Creek, between the BHP WAIO MAC operations to the southwest and BHP WAIO Yandi operations to the north. Located approximately 11 km southeast of the Study Area.
- MAC Reference 2 (MACREF2): series of permanent pools and riffles located on Marillana Creek, upstream of the confluence with the un-named tributary and just outside the Study Area.
- Weeli Wolli Spring (WWS): spring site on Weeli Wolli Creek, within the Weeli Wolli Spring Priority 1 PEC. Located 31 km to the southeast of the Study Area.
- Ben’s Oasis (BENS): spring site on Weeli Wolli Creek which represents the second occurrence of the Weeli Wolli Spring Priority 1 PEC. Located 41 km southeast of the Study Area.
- Skull Spring (SS): spring site on the Davis River. Designated a wetland of subregional significance by Kendrick and McKenzie (2001) due to the presence of permanent springs, large permanent pools, large fish fauna, waterbird use and richness of aquatic vegetation. Skull Springs lies approximately 228 km to the northeast of the Study Area.
- Running Waters (RW): spring site on the Davis River. Running Waters was also designated a wetland of subregional significance by Kendrick and McKenzie (2001) for the same ecological values as Skull Springs. Running Waters is 23 km downstream of Skull Springs (Figure 3.5)

3.2.4 Habitat

Habitat characteristics were recorded at each site to provide information on the variability of aquatic habitat present, and to assist in explaining patterns in aquatic faunal assemblages. Details of in-stream habitat and sediment characteristics were recorded by the same team member at all sites to reduce the potential for habitat differences related to subjective recordings by different personnel. Habitat characteristics recorded included percent cover by inorganic sediment, submerged macrophyte, floating macrophyte, emergent macrophyte, algae, large woody debris (LWD), detritus, roots, and trailing vegetation. Details of substrate composition included percent cover by bedrock, boulders, cobbles, pebbles, gravel, sand, silt, and clay.

3.2.5 Water quality

Water quality variables were recorded *in situ* at each site with a portable YSI Pro Plus multimeter. *In situ* variables included pH, electrical conductivity (EC), dissolved oxygen (DO), and water temperature (Plate 3.1). Undisturbed water samples were taken for laboratory analyses of ionic composition, nutrients, dissolved metals, and turbidity. All water quality analyses were undertaken by ALS, a NATA accredited chemical analysis laboratory.

All water quality variables measured included:

- *In situ* – pH, DO (% and mg/L), EC (µS/cm), water temperature (°C) and redox (mV);
- Ionic composition - Ca, K, Mg, Na, HCO_3, Cl, SO_4, CO_3, alkalinity and hardness (mg/L);
- Water clarity – turbidity (NTU);
- Nutrients – nitrite (N_NO_2), nitrate (N_NO_3), nitrogen oxides (N_NOx), ammonia (N_NH_3), total nitrogen (total N) and total phosphorus (total P) (all in mg/L); and
- Dissolved metals – Al, As, B, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, S, Se, U, V and Zn (mg/L).

Samples collected for dissolved metals were filtered through 0.45 µm Millipore nitrocellulose filters in the field. Nutrient samples were filtered by Australian Laboratory Services (ALS) in the laboratory as part of their analytical methods. Following best practice and to minimise any potential for contamination, all water samples were collected using clean Nalgene sample bottles, and clean/new filters and syringes (Ahlers *et al.*, 1990; Batley, 1989; Madrid & Zayas, 2007). All water quality sampling equipment was stored in polyethylene bags, and samplers wore polyethylene gloves whilst sampling water quality.

Plate 3.1: Taking *in situ* water quality measurements at MarC6 (photo by Biologic ©).

All water samples were kept on ice in an esky whilst in the field, and either refrigerated (ions, dissolved metals, nutrients, general water), or frozen (total nutrients) as soon as possible for subsequent transport to the ALS laboratory.

3.2.6 Wetland flora

Macrophytes are important structural and biological components of lowland streams, providing aquatic fauna with habitat, breeding sites, food and cover from predators. Submerged macrophytes and emergent riparian vegetation were collected from each site, where present. Submerged macrophytes were hand collected and placed in sample containers with sufficient water from the site to ensure the collected material did not dry out or degrade. Roots, stem and flowering/fruiting bodies from emergent and riparian sedges and rushes were hand collected, ensuring sufficient material to allow confident identification. The emergent samples were assigned a unique number and pressed in the field. All specimens collected were processed as per WA Herbarium guidelines and identified in the Biologic laboratory.

3.2.7 Zooplankton (microinvertebrate fauna)

Zooplankton are microscopic invertebrates living near the surface of a water body, and include micro-crustacea (ostracods, copepods and cladocera) and rotifers. They form a vital component of aquatic food webs, feeding upon phytoplankton, bacteria and detritus, and providing an important food source for higher invertebrate consumers and fish. They are generally poor swimmers, instead relying on flow for dispersal.

Zooplankton can be useful bioindicators of water quality, eutrophication, productivity and disturbance because their development and distribution are subject to both abiotic (temperature, salinity, stratification, presence of pollutants, water flow) and biotic parameters (limitation of food, predation and competition) (Ramchandra *et al.*, 2006). Many zooplankton species are known to be highly sensitive to a wide range of pollutants. The use of zooplankton assemblages as bioindicators is most effective in lentic and slow-flowing rivers, where they occur in abundance (ANZG, 2018). In fast-flowing river systems, densities may be greatly reduced due to dilution, or absent where high flows prevent populations from establishing.

Samples were collected by gentle sweeping over an approximate 15 m distance with a 53 μm mesh pond net (Plate 3.2). Samples were preserved in 100% ethanol in the field and sent to Dr Robert Walsh (Zooplankton taxonomist; Australian Waterlife).

In the laboratory, zooplankton samples were sorted using a Greiner tray under a low power dissecting microscope. All micro-crustacea were removed from samples and identification made under a compound microscope, to the lowest possible level of taxonomy (genus or species). Rotifera were identified from a 1 ml aliquot taken from the sample, using a Sedgwick rafter counting tray on a compound microscope.

Plate 3.2: Collecting the zooplankton sample at MACREF1 (photo by Biologic ©).

3.2.8 Hyporheos fauna

The hyporheic zone is an ecotone between the surface and groundwater, and provides a number of ecosystem services to both habitats, including mediating exchange processes, regulating water flows and transfer of nutrients, carbon, oxygen and nitrates, as well as the maintenance of biodiversity (Boulton, 2001; Dole-Olivier & Marmonier, 1992a; Edwards, 1998). Fauna utilising this habitat are also an ecotone between surface and groundwater, with representatives of both benthic epigean species and stygofauna. Benthic macroinvertebrates migrate vertically to exploit hyporheic habitats as a nursery to protect juveniles from predation

(Bruno *et al.*, 2012; Jacobi & Cary, 1996), and during times of floods (Dole-Olivier & Marmonier, 1992b; Edwards, 1998; Palmer *et al.*, 1992), drought (Coe, 2001; Cooling & Boulton, 1993; Hose *et al.*, 2005), and disturbance in food supplies (Edwards, 1998). The hyporheic zone serves to enhance the resilience of the benthic community to disturbance and influence river recovery following perturbations. Hyporheos[1] fauna have been used worldwide as an indicator of ecosystem health, especially in ephemeral creeks, with reported responses to disturbances such as metal pollution and eutrophication (Boulton, 2014; Leigh *et al.*, 2013; Moldovan *et al.*, 2013; Pacioglu & Moldovan, 2016).

At each site, the hyporheic zone was sampled using the Karaman-Chappuis (karaman) method (Chappuis, 1942; Karaman, 1935). This involved digging a hole (approximately 20 cm deep, 40 cm diameter) in alluvial sediments adjacent to the water's edge. The hole was swept at three-time intervals with a modified 110 µm mesh plankton net; (i) immediately once it had filled with water, (ii) after approximately 30 minutes, and (iii) then again at the completion of sampling at that site. Although Bou-Rouch (Bou, 1974) sampling has widely been used to sample the hyporheic zone, the karaman method has been found to be more effective, with a greater diversity of taxa collected (Canton & Chadwick, 2000; Strayer & Bannon-O'Donnell, 1988).

Hyporheic samples were preserved in 100% ethanol in the field and returned to the Biologic laboratory for processing. Hyporheos fauna present were removed by sorting under a low power dissecting microscope. Specimens were identified in-house. Where necessary, some dry 2020 specimens were sent to appropriate taxonomic experts for identification (i.e., Jane McRae for Cladocera, Copepoda and Ostracoda).

3.2.9 Macroinvertebrates

Aquatic macroinvertebrates are used worldwide as indicators of ecosystem health for a number of reasons: they are ubiquitous; relatively easy to collect; have high species diversity and varying sensitivity to environmental disturbances; have relatively long life cycles; and are continuously exposed to environmental conditions and constituents of the surface water they inhabit (Bressler *et al.*, 2006; Cain *et al.*, 1992; Carew *et al.*, 2007; Hodkinson & Jackson, 2005). In Australia, the inherent value in using aquatic macroinvertebrates as key biological indicators is evidenced by their inclusion in river health initiatives across the country, including the Monitoring River Health Initiative (Choy & Thompson, 1995), the Australian River Assessment System (AusRivAS) (Chessman, 1995, 2003; Wright *et al.*, 1993), and the Framework for the Assessment of River and Wetland Health (Norris *et al.*, 2007), to name a few.

Macroinvertebrate sampling was conducted with a 250 µm mesh D-net to selectively collect the macroinvertebrate fauna. At each site, sampling was undertaken across as many habitats as possible, including open water, macrophyte beds, large woody debris (LWD), leaf litter and

[1] Fauna residing in the hyporheic zone with intent. Surface water species utilising the zone for protection against perturbations in the river environment and obligate groundwater species, are collectively known as hyporheos fauna (Brunke & Gonser, 1997).

edge habitat. The kick-sweep method was used in open areas, riffles and along edge habitat, whereby the sediments were disturbed (kicked) and the water column immediately swept with the dip net. Each sample was washed through a 250 μm sieve to remove fine sediment, with leaf litter and other coarse debris removed by hand. The net was thoroughly cleaned between sites to avoid cross contamination. Samples were preserved in 100% ethanol in the field (equivalent to ~70% ethanol including the macroinvertebrate sample) and transported to the Biologic laboratory for processing. Sorting was conducted under a low power dissecting microscope. Specimens were identified to the lowest possible level (genus or species level) and enumerated to $\log_{10}$ scale abundance classes (i.e., 1 = 1 individual, 2 = 2 - 10 individuals, 3 = 11 - 100 individuals, 4 = 101-1000 individuals, 5 = >1000). All macroinvertebrate groups were identified using in-house expertise.

3.2.10 Fish

Fish sampling included a variety of methods to collect as many species and individuals as possible. Methods included light-weight fine mesh gill nets (10 m net, with a 2 m drop, using 10 mm, 13 mm, 19 mm and 25 mm stretched mesh) set across the creek/pool, seine netting (10 m net, with a 2 m drop and 6 mm mesh; Plate 3.3) and direct observation. The seine was deployed in shallow areas with little vegetation or large woody debris, and up to three seine hauls were undertaken per site. Fish were identified in the field and standard length (SL[2]) measured. All fish were released alive to the site where they were collected.

Plate 3.3: Fish sampling using a seine net at MarC3 (photo by Biologic ©).

3.2.11 Other aquatic fauna

Other vertebrate fauna (i.e., turtles, olive pythons, frogs) observed over the course of the aquatic survey were recorded for each site.

[2] Standard length (SL) - measured from the tip of the snout to the posterior end of the last vertebra or to the posterior end of the midlateral portion of the hypural plate (i.e., this measurement excludes the length of the caudal fin).

3.3 Data analysis

3.3.1 Water quality

Water quality data were compared against the ANZG (2018) default guideline values (DGVs) for the protection of aquatic ecosystems in the tropical north-west of Western Australia (see Appendix B for default values). For this purpose, sites sampled in the current study were classified as lowland rivers. Lowland rivers are those defined as < 150 m elevation (ANZG, 2018).

The primary objective of the guidelines is to "provide authoritative guidance on the management of water quality in Australia and New Zealand …. and includes setting water quality and sediment quality objectives designed to sustain current, or likely future, community values for natural and semi-natural water resources" (ANZG, 2018). DGVs are provided for a range of parameters designed to protect aquatic systems at a low level of risk but are not designed as pass or fail compliance criteria. Rather, exceedances of DGVs are triggers to inform managers and regulators that changes in water quality are occurring and may need to be investigated.

Differing levels of protection are provided within the guidelines, depending on the condition of the ecosystem in question:

- High conservation/ecological value systems - where the goal is to maintain biodiversity with no (or little) change to ambient condition. 99% species protection DGVs for toxicants apply[3].
- Slightly to moderately disturbed systems - where aquatic biodiversity has already been adversely impacted to a small but measurable degree by human activity. The aquatic ecosystem remains in a healthy condition and ecological integrity is largely retained. The aim is to maintain current biodiversity and ecological function. 95% species protection DGVs for toxicants apply.
- Highly disturbed systems - are measurably degraded and of lower ecological value. Guideline aims for these systems may be varied and more flexible, ranging from maintenance of the current yet modified ecosystem that supports management goals, to continual improvement in ecosystem condition. For toxicant, the 90% or 80% species protection DGVs may be applied.

Marillana Creek is located within an area of historic pastoral use, with mining nearby. As such, sites sampled in the current study were classified as slightly to moderately disturbed and the 95% DGVs applied. The 99% toxicity DGVs were also included in comparisons for context.

[3] For toxicants, DGVs were derived using the species sensitivity distribution (SSD) approach; methods are described in ANZG (2018). Refer to (Warne *et al.*, 2018) for updated GVs. Where the SSD approach could not be used, the less preferred 'assessment-factor approach' was used, following methods detailed in ANZG (2018). For toxicants, DGVs relate to differing levels of species protection, i.e., the 99% DGVs protect 99% of species, the 95% DGVs protect 95% of species present, and so on.

Two DGVs relating to nutrient concentrations are provided for within the default ANZG (2018) guidelines:

- a toxicity DGV above which direct toxic effects to aquatic biota can be expected (ammonia, nitrate); and
- a eutrophication DGV, above which nutrient concentrations are such that algal blooms and eutrophic conditions can be expected (nitrogen oxides, total nitrogen, total phosphorus).

The guidelines have recently been updated to reflect a better understanding of physical and chemical stressors, the availability of additional monitoring data, the addition of recent toxicity data in DGVs for several toxicants, a weight of evidence approach, and the fact that water quality varies greatly across ecosystem types and regions (ANZG, 2018). The guidelines are now presented via an interactive online platform to improve usability and facilitate updates as new information becomes available. While information relating to management frameworks, background to derivation of DGVs, and approaches for sampling design and monitoring programs are available online, DGVs are not currently presented for all ecoregions. The Study Area falls within the Indian Ocean Inland Waters region, data for which is not currently available online. As such, data from the current study were compared against the ANZECC and ARMCANZ (2000) DGVs for systems within the tropical north-west of Western Australia (as presented in ANZG, 2018).

3.3.2 Invertebrates

All taxa recorded from hyporheic samples were classified using Boulton (2001) categories:

- stygobite – obligate groundwater species, with special adaptations to survive such conditions;
- permanent hyporheos stygophiles - epigean species (living on or near the surface of the ground) which can occur in both surface- and groundwaters, but is a permanent inhabitant of the hyporheos;
- occasional hyporheos stygophiles – use the hyporheic zone seasonally or during early life history stages; and
- stygoxene (species that appear rarely and apparently at random in groundwater habitats, there by accident or seeking refuge during spates or drought; not specialised for groundwater habitat).

Additionally, one further hyporheic classification was imposed:

- possible hyporheos stygophile – likely to be hyporheos fauna, but due to taxonomic resolution or a lack of ecological information we are unable to say this with certainty.

All invertebrates collected were compared against appropriate threatened and priority species lists including the *Biodiversity Conservation Act 2016,* the *Environment Protection and Biodiversity Conservation Act 1999*, the International Union for Conservation of Nature (IUCN), Australian Society for Fish Biology Conservation List 2016, and Priority Fauna recognised by the DBCA (see Appendix A). In addition, species were assigned to one of the following conservation categories based on species distributions:

- Cosmopolitan – species is found widely across the world;
- Australasian – species is found across Australia, New Guinea and neighbouring islands, including those of Indonesia;
- Australian endemic – species is only found in Australia;
- Northern Australia – species with distributions across the northern, tropical regions of the Australian continent;
- North Western Australia – found across northern W.A., including the Pilbara and Kimberley regions;
- Western Australian endemic – only known from W.A. (is restricted to, but is widely distributed across the state);
- Pilbara endemic - restricted to the Pilbara region of Western Australia;
- Short range endemic (SRE) – an SRE is a species occupying an area of less than 10,000 km^2 (Harvey, 2002). Such species have traits which make them vulnerable to disturbance and changes in habitat, and affords them high conservation value; and
- Indeterminate distribution – taxa could not be assigned to one of the above, as there is currently insufficient knowledge on either its distribution or taxonomy to assess its level of endemism.

Macroinvertebrate data were also compared against nearby sites sampled during the Pilbara Biological Survey (PBS) and previous aquatic surveys by Biologic and others (see Section 4.2). To undertake this comparison, the dataset had to be amalgamated, and taxonomy aligned, to ensure any differences in taxonomic knowledge between samplers and years was appropriately accounted for.

Univariate analysis was undertaken was undertaken in SPSS v21. This included two-way analysis of variance (ANOVA) to compare richness (zooplankton and macroinvertebrate richness) between creeks (the Study Area vs nearby creeks, as sampled during previous surveys) and between season (dry vs wet). A Levene's test was undertaken prior to analysis to test for equality of variances and ensure assumptions of the ANOVA test were met.

Zooplankton and macroinvertebrate assemblage structure were then analysed using multivariate techniques in PRIMER v7 (Clarke & Gorley, 2015), including cluster analysis and ordination. Ordination was by non-metric Multi-Dimensional Scaling (nMDS), which, unlike other ordination techniques uses rank orders, and therefore can accommodate a variety of different types of data. Ordination was based on the Bray-Curtis similarity matrix (Bray & Curtis, 1957). The BEST routine was utilised to determine whether there were any relationships between biotic assemblages and environmental variables (water quality and in-stream habitat characteristics). BVSTEP was used due to the size of the dataset, in particular the large number of variables included in analysis.

3.3.3 Fish

Length-frequency analysis was undertaken for each fish species recorded, whereby each species was classified into four age classes based on body size (SL mm). Age classes were determined from the literature (Allen *et al.*, 2002; Puckridge & Walker, 1990) (Table 3.4).

Table 3.4: Standard lengths used for each age class for each fish species recorded.

	Standard Length (mm)		
Age class	**Western rainbowfish**	**Spangled perch**	**Pilbara tandan**
New recruit	< 30	< 30	< 30
Juvenile	31-40	31-50	31-70
Sub-adult	41-50	51-70	71-90
Adult	>50	>70	>90

4 RESULTS

4.1 Database searches

The database searches identified 329 records of aquatic fauna taxa and waterbirds (Table 4.1). The total included 279 species of invertebrates and 50 species of vertebrates. Insects and crustaceans accounted for over 61% of all taxa previously recorded.

Table 4.1: Aquatic fauna identified within 40 km of the Study Area from the database searches.

Type	Taxonomic Group	Common Name	Number of Taxa
Invertebrate	Protozoa	Protists	4
Invertebrate	Rotifera	Rotifers	21
Invertebrate	Annelida	Segmented Worms	18
Invertebrate	Nematoda	Roundworms	5
Invertebrate	Platyhelminthes	Flatworms	1
Invertebrate	Arachnida	Mites	21
Invertebrate	Insecta	Insects	140
Invertebrate	Crustacea	Crustaceans	63
Invertebrate	Mollusca	Molluscs	5
Invertebrate	Cnidaria	Hydras	1
Vertebrate	Actinopterygii	Fish	4
Vertebrate	Reptilia	Snakes	1
Vertebrate	Amphibia	Frogs	9
Vertebrate	Aves	Waterbirds	36
		Total	**329**

Of the taxa recorded within 40 km of the Study Area, nine species of waterbird are of conservation significance (Table 4.2). The waterbird *Calidris ferruginea* (curlew sandpiper) is listed as Critically Endangered under the State BC Act and Federal EPBC Act. It is also listed as migratory under the EPBC Act, as well as Near Threatened on the IUCN Red List of Threatened Species. The curlew sandpiper is known to occur in temporary freshwater wetlands. The waterbird *Rostratula australis* (Australian painted snipe) is listed as Endangered under the State BC Act, Federal EPBC Act and IUCN Red List. Australian painted snipe has a single, small population which has shown rapid and continued decline due to habitat loss (BirdLife International, 2016). It is more common in eastern Australia, with more scattered locations within Western Australia. The remaining conservation significant waterbirds are all listed as migratory under both the State BC Act and Federal EPBC Act. These include *Charadrius veredus* (Oriental plover), *Onychoprion anaethetus* (bridled tern), *Actitis hypoleucos* (common sandpiper), *Calidris acuminata* (sharp-tailed sandpiper), *Tringa glareola* (wood sandpiper), *Tringa nebularia* (common greenshank) and *Calidris melanotos* (pectoral sandpiper). The pectoral sandpiper is also listed as Near Threatened (IUCN, 2021). All migratory species are matters of national environmental significance (MNES) under the EPBC Act.

One MNES reptile, the Pilbara olive python (*Liasis olivaceus barroni*), was reported in the database search. The Pilbara olive python is restricted to the Pilbara region and can be found in gorges, waterholes and on escarpments. It is currently listed as Vulnerable (VU) (Federal EPBC Act and State BC Act).

Table 4.2: Endemic (to search area) and conservation significant aquatic fauna identified within 40 km of the Study Area from the database searches.

Taxonomic Group	Family	Taxa	WA Listing	EPBC Listing	IUCN Listing	Endemic to Search Area
Annelida	Naididae	*Ainudrilus* sp. WA26				Y
Crustacea	Candonidae	*Areacandona* sp. 1				Y
Crustacea	Candonidae	*Deminutiocandona mica*				Y
Crustacea	Candonidae	*Meridiescandona `cowrae`*				Y
Crustacea	Candonidae	*Meridiescandona marillanae*				Y
Crustacea	Candonidae	*Meridiescandona facies*				Y
Crustacea	Candonidae	*Meridiescandona* sp. 1				Y
Crustacea	Candonidae	*Notacandona boultoni*				Y
Crustacea		Harpacticoida sp. 4				Y
Crustacea	Paramelitidae	*Maarrka weeliwolli*				Y
Crustacea	Tainisopidae	*Pygolabis weeliwolli*				Y
Arachnida	Arrenuridae	*Arrenurus* sp. nov. 1				Y
Insecta	Coenagrionidae	*Agriocnemis kunjina* (Pilbara wisp)			VU	
Insecta	Coenagrionidae	*Austroagrion pindrina* (Pilbara billabongfly)			VU	
Insecta	Isostictidae	*Eurysticta coolawanyah* (Pilbara pin)			VU	
Insecta	Corduliidae	*Hemicordulia koomina* (Pilbara emerald)			VU	
Insecta	Lindeniidae	*Ictinogomphus dobsoni* (Pilbara tiger)			NT	
Reptilia	Pythonidae	*Liasis olivaceus barroni* (Pilbara olive python)	VU	VU		
Aves	Charadriidae	*Charadrius veredus* (oriental plover)	MI	MI		
Aves	Laridae	*Onychoprion anaethetus* (bridled tern)	MI	MI		
Aves	Rostratulidae	*Rostratula australis* (Australian painted snipe)	EN	EN	EN	
Aves	Scolopacidae	*Actitis hypoleucos* (common sandpiper)	MI	MI		
Aves	Scolopacidae	*Calidris acuminata* (sharp-tailed sandpiper)	MI	MI		
Aves	Scolopacidae	*Calidris ferruginea* (curlew sandpiper)	CR	CR & MI	NT	
Aves	Scolopacidae	*Calidris melanotos* (pectoral sandpiper)	MI	MI		
Aves	Scolopacidae	*Tringa glareola* (wood sandpiper)	MI	MI		
Aves	Scolopacidae	*Tringa nebularia* (common greenshank)	MI	MI		

NT= Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered, MI = Migratory species (see Appendix A for descriptions of conservation codes).

The database search also identified 17 invertebrates of significance, including five listed taxa and 12 that were endemic to the search area (Table 4.2). The listed species include the damselflies *Agriocnemis kunjina* (Pilbara wisp), *Austroagrion pindrina* (Pilbara billabongfly), and *Eurystictica coolawanyah* (Pilbara pin), as well as the dragonflies *Hemicordulia koomina* (Pilbara emerald) and *Ictinogomphus dobsoni* (Pilbara tiger).

The Pilbara wisp *Agriocnemis kunjina* is currently listed as Vulnerable on the IUCN Redlist of Threatened Species (IUCN, 2021). *A. kunjina* has been recorded from only ten sites (Dow, 2017a). While the IUCN listing reports an estimated extent of occurrence of 10, 735 km^2 (Dow, 2017a), Bush *et al.* (2014) estimated the extent of suitable habitat was much lower, at 5, 291 km^2. Its habitat is considered under threat from declining water levels (Dow, 2017a). Records for this species exist as recently as 2018; however, these records were submitted by the general public and are unverified. The most recent record with a verified identification from an expert taxonomist was 2005 (ALA, 2021). *A. kunjina* was not recorded during the PBS (Pinder *et al.*, 2010) and has not been recorded by the others from sites within 40 km of the Study Area.

The Pilbara billabongfly *Austroagrion pindrina* is currently listed as Vulnerable on the IUCN Redlist (IUCN, 2021). Little is known about this damselfly species, though it appears to inhabit inland permanent rivers and streams, including waterfalls, as well as freshwater marshes and pools. *A. pindrina* is endemic to the Pilbara region and has an estimated extent of occurrence of 10, 755 km^2 (Dow, 2017b). At the time of the IUCN assessment in 2016 there were less than ten records of *A. pindrina*; however, this assessment did not appear to include grey literature or records from baseline surveys for developments. Pinder *et al*. (2010) recorded 67 occurrences of this species across the Pilbara during the PBS.

The Pilbara pin damselfly, *Eurysticta coolawanyah* is currently listed as Vulnerable on the IUCN Red List (IUCN, 2021). This listing was based on its collection from less than five locations. Although the listing was revised recently (2016), the revision did not consider grey literature records (baseline surveys and impact assessments associated with mining and development in the region). Its extent of occurrence, based on a polygon around the known occupied areas (four locations listed in the IUCN listing), is 7,937 km^2 (Dow, 2019a); however, Bush *et al.* (2014) indicated the current extent of suitable habitat is likely much higher (~ 298,177 km^2). Including the PBS and grey literature records (sampling programs undertaken by the authors and others), the species has now been recorded from numerous locations in the Pilbara, albeit in low numbers and with a disjunct distribution (Pinder *et al.* 2010, Jess Delaney, unpub. data).

The Pilbara emerald *Hemicordulia koomina*, is also currently listed on the IUCN Redlist as Vulnerable (IUCN, 2021). Its listing was based on it being known from only five sites in the Pilbara (Millstream station, Koomina Pools on Tanberry Creek, Palm Pool south of Karratha, Fortescue Crossing, and Millstream Spring). Lowering water levels from groundwater abstraction and climate change were highlighted as a considerable threat to this species, along with its severely fragmented distribution (IUCN, 2021). Like *E. coolawaynah*, the IUCN listing for *H. koomina* was updated fairly recently (2016), but the update did not appear to take into account grey literature records. Including known locations reported in Pinder *et al.,* (2010) and sites known by the authors, *H. koomina* likely occurs at more than 15 sites across the Pilbara. The IUCN listing did indicate that its maximum known extent of occurrence based on five locations was 6,504 km^2 (Dow, 2019b); however, Bush *et al.,* (2014) provided a much greater estimate of the current extent of suitable habitat (119,416 km^2). This species is still considered rare and is infrequently collected and rarely recorded.

The Pilbara tiger *Ictinogomphus dobsoni* is endemic to the Pilbara region and is currently listed on the IUCN Redlist as Near Threatened (IUCN, 2021). This 2016 assessment was based on a record of less than ten locations. Pinder *et al*. (2010) recorded this species from 16 locations across the Pilbara. It is thought to occur in high local abundances (Dow, 2017b).

Seven species of stygal ostracods were highlighted in the database search as being restricted to the search area. Of these, three are unlikely to occur within the Study Area; *Deminutiocandona mica* (known only from its type locality in Weeli Wolli Spring), *Meridiescandona* sp. 1 (also known only from Weeli Wolli Spring), and *Meridiescandona* `*cowrae*` (recorded from a single bore 39 km north of the Study Area). Given the highly restricted occurrences of these taxa, they are unlikely to occur outside their known range. The remaining taxa may all occur within the Study Area: *Meridiescandona facies* and *Notocandona boultoni* are both known from Weeli Wolli Creek and Yandicoogina Creek, and *Areacandona* sp. 1 and *Meridiescandona marillanae* have only been recorded from bores along Marillana Creek.

Other invertebrate taxa considered to be restricted to the search area include an oligochaete (*Ainudrilus* sp. WA26), harpacticoid copepod (Harpacticoida sp. 4), stygal amphipod (*Maarka weeliwolli*) and one species of isopod (*Pygolabis weeliwolli*). The stygal amphipod is an SRE known only from groundwater and hyporheic zones of Marillana and Weeli Wolli creeks. The stygobitic isopod *Pygolabis weeliwolli* is a known SRE, with its range restricted to the groundwater and hyporheos of Weeli Wolli Creek and Marillana Creek, as well as groundwater bores within the Yandicoogina tenement (Biota, 2010).

4.2 Literature review

Previous aquatic sampling has been conducted within the Study Area at Flat Rocks (site MarC6 in the current study) (Streamtec, 2004; WRM, 2015), and on downstream sections of Marillana Creek within the BHP WAIO Yandi tenement (Masini, 1988; WRM, 2018). Studies have also sampled sites nearby to varying degrees, i.e., Pinder *et al.* (2010). Information relating to sites sampled and ecological components surveyed is provided in Table 4.3.

Table 4.3: Information relating to previous sites sampled, sampling occasions and ecological components surveyed during aquatic surveys undertaken by others within 40 km of the Study Area.

Reference	Sites sampled	Sampling occasions	Components sampled
Masini (1988)	Junction: Marillana and Yandicoogina Creeks (sites 24 and 25) Weeli Wolli Spring (sites 26 to 32)	Wet-1983	Water quality Habitat assessment Fringing vegetation Macrophytes Phytoplankton Benthic microalgae Waterbirds Fish
Streamtec (2004)	Flat Rocks (current MarC6 within Study Area) Weeli Wolli Spring	Dry-2001 Wet-2002 Wet-2003 Dry-2003	Water quality Macroinvertebrates Fish
Pinder *et al.* (2010)	Weeli Wolli Spring Mulga Downs Outcamp Claypan	Dry-2003 Wet-2004 Wet-2005 Dry-2006	Water quality Zooplankton Macroinvertebrates
WRM (2015)	Flat Rocks (current MarC6 within Study Area) Flat Rocks Downstream (FRDR; within Study Area) Sites MC1 to MC7	Wet-2014 Dry-2014	Water quality Habitat assessment Zooplankton Hyporheos fauna Macroinvertebrates Fish
WRM (2018)	Sites MC1 to MC7 as sampled in 2014 Additional sites MC1-B, MC8, MC9	Wet-2017 Dry-2017	Water quality Habitat assessment Zooplankton Hyporheos fauna Macroinvertebrates Fish

In the wet season of 1983, Masini (1988) sampled a total of 76 sites across the Pilbara, with the objective of producing an inventory of permanent and ephemeral inland surface waters in the region, and a means for establishing priorities for management and/or reservation. The survey included water quality (with a particular focus on nutrient status), habitat assessments, fringing vegetation, emergent and submerged macrophytes, phytoplankton, benthic microalgae, waterbirds and fish. From the sites near the Study Area, Masini (1988) recorded seven genera of Chlorophyta (green algae) and one genus of Cyanophyta (blue-green algae). Diatoms and Charophyta (charophytes) were also present. Fish species were not listed per site within Masini (1988), but rather by wetland type, though it was indicated that common freshwater fish such as western rainbowfish (*Melanotaenia australis*) and spangled perch (*Leiopotherapon unicolor*) were recorded from sites on or near the confluence of Marillana and Yandicoogina Creeks. Two waterbirds were recorded within the vicinity of the Study Area; white-faced heron (*Ardea novaehollandiae*) and black duck (*Anas superciliosa*). Neither of these species are listed as migratory or for conservation significance.

As part of the PBS, water quality and aquatic fauna (zooplankton and macroinvertebrates) were sampled at 100 sites across the Pilbara, between 2003 and 2006 (Pinder *et al.*, 2010). Aquatic macrophytes and riparian flora were also sampled in conjunction with the aquatic fauna (Gibson *et al.*, 2015). The PBS included most wetland types from the region, such as wetlands, river pools, claypans, rock pools and springs. Overall, invertebrate community composition (relative richness of different species assemblages) was found to be associated with flow, estimated permanence, water chemistry, macrophytes and sediments (Pinder *et al.*, 2010). Only two PBS sites were sampled within 40 km of the Study Area; Weeli Wolli Spring (at a location colloquially referred to as whirlwind pool, upstream of the first crossing) and Mulga Creek Outcamp claypan. A total of 47 zooplankton and 121 macroinvertebrate taxa were recorded from Weeli Wolli Spring, over two seasons (September 2003 and May 2005). Mulga Creek Outcamp claypan was sampled in May 2004 and August 2006. A total of 52 zooplankton and 74 macroinvertebrate taxa were recorded from this site. Of these taxa, three are listed (damselflies *Eurysticta coolawanyah* and *Austroagrion pindrina*, and dragonfly *Ictinogomphus dobsoni*), and three are of further scientific and conservation interest (the stygal mites *Wandesia* sp. P1 and *Limnesia* sp. P4, and the stygal amphipod *Chydaekata* sp. E; Table 4.4).

Wandesia sp. P1 (nr *glareosa*) is a known but undescribed Pilbara endemic species. It was recorded during the PBS from river pools and springs. While *Limnesia* sp. 4 is a Pilbara endemic, it is widespread across the region. It has a relatively disjunct distribution in the Pilbara, being known previously from the Robe Valley (WRM, 2017). Although the *Chydaekata* sp. E is an undescribed morphotype, this species is previously known and constitutes a Potential SRE (Data Deficient). Current knowledge suggests it is restricted to Marillana Creek, Yandicoogina Creek and Weeli Wolli Creek. Genetic analysis undertaken by Biologic and others have indicated that most paramelitid species have ranges in the tributary-scale (Biologic, 2020a; Finston *et al.*, 2008; Finston *et al.*, 2011; Finston *et al.*, 2007). Aquatic survey reports prepared for various BHP Projects were also provided for this review, including Streamtec (2004) and

WRM (2015, 2018). Sampling by Streamtec (2004) included water quality, macroinvertebrates, and fish. A total of 12 sites were sampled, one of which was located within 40 km of the Study Area (Weeli Wolli Spring), and one within the Study Area itself (Flat Rocks). In November 2003 (the only sampling occasion for which data was included in Streamtec 2004), 80 invertebrate taxa were recorded; however, a large number of invertebrates were only identified to a high level, i.e., water mites to Acarina spp., segmented worms to Oligochaeta spp., non-biting midges to Chironomidae, etc. In addition, the invertebrate list included some zooplankton taxa (micro-crustacea, although identified to Class only). One conservation significant taxa was recorded from Flat Rocks, the Pilbara tiger dragonfly *Ictinogomphus dobsoni*. Three species of freshwater fish were recorded from the two sites within 40 km of the Study Area, including western rainbowfish, spangled perch and Hyrtl's tandan catfish (*Neosilurus hyrtlii*) (Streamtec, 2004). The latter has since been re-named (Pilbara tandan; *Neosilurus* sp.) as genetic analyses discovered Pilbara specimens are genetically distinct from other northern Australian populations of *N. hyrtlii* (Unmack, 2013).

In the wet and dry seasons of 2014, WRM (2015) undertook aquatic surveys within and adjacent to BHP's Yandi tenement. Up to nine sites were sampled in both seasons. Five reference sites were also sampled, including Flat Rocks and a permanent pool located downstream of Flat Rocks (referred to as Flat Rocks downstream; located within the current Study Area). Aquatic surveys included water quality, habitat, zooplankton, hyporheos fauna, macroinvertebrates, and fish. A total of 101 zooplankton taxa and 212 macroinvertebrate taxa were recorded over the course of the study, including reference sites outside of the 40 km search area (WRM, 2015). Of these, 16 taxa were recorded within 40 km of Study Area that were of conservation significance or scientific interest: the rotifers *Lecane batillifer*, *Lecane noobijupi* and *Heterolepadella heterostyla*, the copepods *Mesocyclops holynskae* and *Australoeucyclops karaytugi*, the stygobitic ostracod *Gomphodella* n. sp. (BOS334), the hyporheic water mite *Stygolimnochares* nr *australica*, the damselfly *Eurysticta coolawanyah* (IUCN Vulnerable), dragonflies *Nannophlebia injibandi* and *Ictinogomphus dobsoni* (IUCN Near Threatened), beetles *Tiporus tambreyi*, *Haliplus halsei* and *Haliplus pinderi* and stygal amphipods *Chydaekata* sp., as well as morphospecies referred to by WRM as Paramelitidae sp. D and Paramelitidae sp. B.

Within Australia, the rotifer *Lecane batillifer* appears to be restricted to the Pilbara, though the species is also known from China and Thailand. *Lecane noobijupi* is endemic to Western Australia and is thought to have a disjunct distribution, while *Heterolepadella heterostyla* is thought to have a cosmopolitan distribution, but is rarely collected from Pilbara inland waters (WRM, 2015). The ostracod *Gomphodella* n. sp. (BOS334) was recorded from the hyporheos of Marillana Creek, and has previously been recorded from bores in the Yandi area as well as the hyporheic zone of Weeli Wolli Creek. It was considered a potential SRE by WRM (2015) due to its relatively restricted distribution. The aquatic mite *Stygolimnochares* nr *australica* represents either a range extension of Queensland species *Stygolimnochares australica*, or a new species. In the Pilbara, *Stygolimnochares* nr *australica* is also known from Fortescue River

Upstream (located on Fortescue River approximately 114 km south east from the Study Area) and Gudai-Darri (formerly Koodaideri) Spring. These three locations are the only records of the taxa currently.

The amphipods *Chydaekata* sp., Paramelitidae sp. D (also referred to as morphospecies Paramelitidae `Genus 2 sp. B03` by others) and Paramelitidae sp. B (also referred to as Paramelitidae `Genus 2 sp. B02` by others) were recorded from Marillana Creek by WRM (2015). Given the location records for *Chydaekata* sp., it is likely this species is *Chydaekata* sp. E. The two Paramelitidae morphotypes are more difficult to determine which species they likely represent. Recent molecular sequencing of amphipods undertaken by Biologic (2020a) for BHP found specimens morphologically identified as Paramelitidae `Genus 2 sp. B03` matched *Chydaekata* sp. E . Furthermore, individuals morphologically identified as Paramelitidae `Genus 2 sp. B02` represented two genetically divergent species (Paramelitidae `sp. Biologic-AMPH023` and Paramelitidae `sp. Biologic-AMPH024`). Paramelitidae `sp. Biologic-AMPH023` is known from Yandicoogina and Marillana Creeks, while Paramelitidae `sp. Biologic-AMPH024` was recorded from Weeli Wolli Creek only (Biologic, 2020a) . Based on this, the three morphotypes recorded by WRM (2015) may in fact represent two species (*Chydaekata* sp. E and Paramelitidae `sp. Biologic-AMPH023`). Either way, the stygal amphipods of this area are considered Potential SRE (Data Deficient) using WAM's three-tier SRE classification system.

The Pilbara pin *Eurysticta coolawanyah* (IUCN Vulnerable), and Pilbara tiger *Ictinogomphus dobsoni* (IUCN Near Threatened) were the two listed species recorded by WRM (2015). The remaining taxa (*Mesocyclops holynskae*, *Australoeucyclops karaytugi, Nannophlebia injibandi*, *Tiporus tambreyi*, *Haliplus halsei* and *Haliplus pinderi*) are all endemic to the Pilbara, though most are commonly recorded throughout the region.

BHP's Yandi tenement was again sampled in the wet and dry seasons of 2017 (WRM, 2018). Up to 13 sites were sampled on each occasion and a total of 92 zooplankton taxa and 222 macroinvertebrate taxa were recorded (WRM, 2018). Nine sites were located on Marillana Creek (MC1 to MC9), downstream of the current Study Area. Flat Rocks (equivalent to MarC6 in the current study) was included in 2014 as a reference site (WRM, 2015), but was removed from the sampling program in 2017 as it was thought to be affected by drawdown and therefore no longer represented an appropriate reference (WRM, 2018). A total of 12 taxa recorded from Marillana Creek were considered to be of interest or conservation significance. These included the rotifer *Lecane* 'bulloid' n. sp., copepod *Australoeucyclops karaytugi*, amphipods *Chydaekata* sp., Paramelitidae sp. D and Paramelitidae sp. B, stygal isopod *Pygolabis weeliwolli*, aquatic mite *Stygolimnochares* nr *australica*, damselfly *Eurysticta coolawanyah* (IUCN Vulnerable), dragonfly *Nannophlebia injibandi*, and Pilbara endemic beetles *Laccobius billi*, *Sternopriscus pilbarensis* and *Haliplus pilbarensis*.

Table 4.4: Results of previous aquatic surveys conducted in the vicinity of the Study Area.

Report Reference	Conservation Significant Aquatic Fauna Recorded	Sites Recorded
Pinder *et al.* (2010)	*Wandesia* sp. P1	Weeli Wolli Spring
	Limnesia sp. P4	Weeli Wolli Spring
	Eurysticta coolawanyah	Weeli Wolli Spring
	Austroagrion pindrina	Weeli Wolli Spring
	Ictinogomphus dobsoni	Weeli Wolli Spring
	Chydaekata sp.	Weeli Wolli Spring
Streamtec (2004)	*Ictinogomphus dobsoni*	Flat Rocks
WRM (2015)	*Lecane batillifer*	MC5
	Lecane noobijupi	Flat Rocks, MC1, MC2, MC4, MC5, MC6, MC7
	Heterolepadella heterostyla	MC5, MC6
	Australoeucyclops karaytugi	Flat Rocks, MC2, MC4, MC6, MC7
	Mesocyclops holynskae	MC6
	Gomphodella n. sp. (BOS334)	MC1, MC6
	Chydaekata sp.	MC5, MC6
	Paramelitidae sp. B	MC5, MC6
	Paramelitidae sp. D	MC5, MC6
	Stygolimnochares nr *australica*	MC6
	Eurysticta coolawanyah	Flat Rocks, MC5, MC7
	Hemicordulia koomina	Flat Rocks
	Nannophlebia injibandi	MC4, MC6, MC7
	Tiporus tambreyi	Flat Rocks, MC1, MC5, MC6
	Haliplus halsei	Flat Rocks, Flat Rocks downstream
	Haliplus pinderi	MC2
WRM (2018)	*Lecane* 'bulloid' n. sp.	MC1-B, MC6
	Australoeucyclops karaytugi	MC1
	Chydaekata sp.	MC1-B, MC7
	Paramelitidae sp. B	MC1, MC1-B, MC5, MC7
	Paramelitidae sp. D	MC7, MC8, MC9
	Pygolabis weeliwolli	MC7
	Stygolimnochares nr *australica*	MC2, MC7
	Eurysticta coolawanyah	MC7, MC8
	Nannophlebia injibandi	MC1-B, MC2, MC9
	Laccobius billi	MC2
	Sternopriscus pilbaraensis	MC2, MC5
	Haliplus pilbaraensis	MC1-B

It is noted here that many invertebrate taxa reported in these surveys are unable to be classified due to taxonomic limitations or impediments (such as damaged or immature specimens), as well as a general lack of reliable information regarding distributions. Records of morphotypes which could not be identified to species-level due to a lack of suitable keys or lack of taxonomy in the Pilbara for that group limits knowledge of occurrences outside of the PBS. This is the case for many taxa, in particular Diptera (true flies), water mites, some Trichoptera (caddisfly) genera (i.e., *Oecetis*) and Hydrochidae beetles (*Hydrochus*). It is likely that several endemic species exist within these groups, but remain undescribed, and subsequently lack distribution information.

4.3 Habitat Assessment

A summary of the overall habitat assessment is provided in Table 4.5 and all raw data in Appendix C. Riparian vegetation throughout the Study Area comprised an open overstorey of

Eucalyptus camaldulensis, *Melaleuca argentea* and *Melaleuca glomerata* over *Cyperus vaginatus*. Weeds were sporadic throughout the Study Area, but were not present in high diversity, density, or abundance. Impacts of cattle were apparent at both Study Area (MarC2 to MarC5) and reference sites (BENS), including trampling of edge sediments. No other major disturbances were noted, with the exception of potential drawdown impacts at MarC6. Although located upstream of current mining, this site is thought to be impacted by drawdown from BHP WAIO Yandi operations (WRM, 2018). Overall, riparian vegetation within the Study Area was considered to be in good condition, with several GDV taxa present. However, emergent macrophytes were showing signs of senescence in the dry season, particularly at MarC6.

While most sites in the Study Area were dominated by transmissive substrates such as pebbles, and gravel, bedrock was more dominant at MarC3 and MarC6. Clay was also more dominant at MarC6, particularly in the dry season. Most sites recorded some sand and silt. At reference sites, bedrock was dominant at MACREF1, MACREF2 and Running Waters, while all other sites generally recorded high contributions of transmissive sediments.

In-stream habitat diversity was high throughout the Study Area, and comprised complex heterogenous substrates with which to support aquatic fauna, such as submerged and emergent macrophytes, large woody debris, algae and detritus. Some seasonal change was evident, with an increase in algae and reduction in submerged macrophyte cover in the wet 2021 recorded at most sites. This is likely a result to flooding associated with the good wet season.

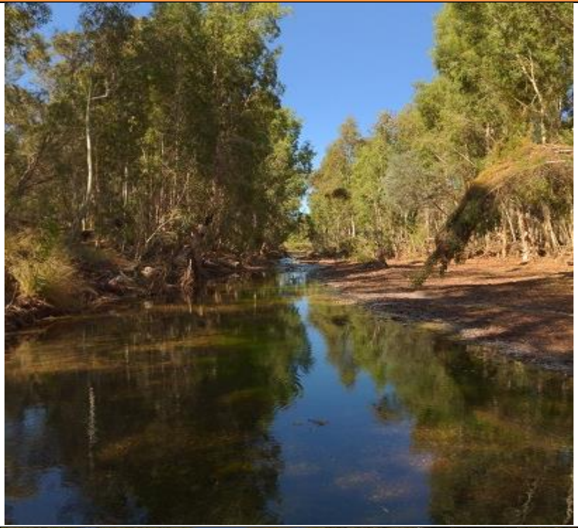
Table 4.5: Summary of aquatic habitats sampled, including site photos.

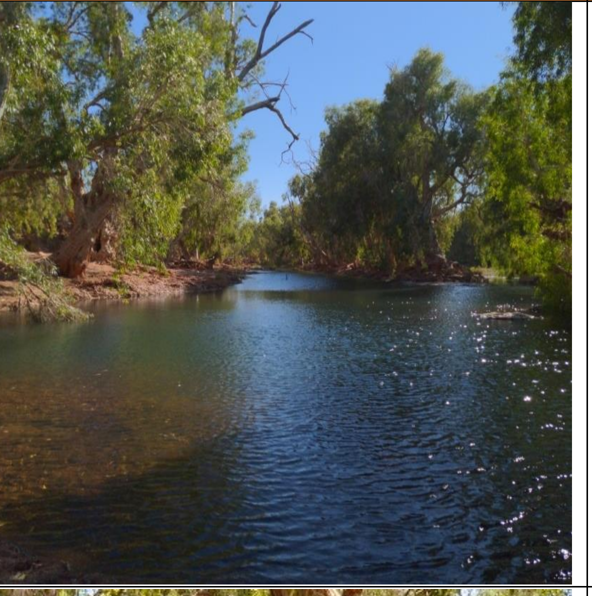
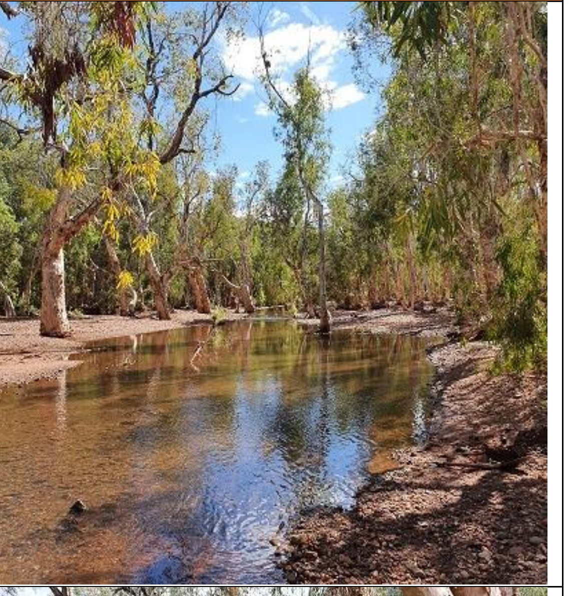
Site	Habitat	Description	Dry 2020 Site Photo	Wet 2021 Site Photo
MarC1 (tributary)	**Permanent pools**	Series of permanent, shallow pools and riffles located on an un-named tributary of Marillana Creek. Open overstorey of *Melaleuca argentea* and *M. glomerata*. In-stream habitat comprising submerged charophytes (*Chara* spp.), emergent macrophytes (*Cyperus vaginatus, Eleocharis geniculata* & *Typha domingensis*), algae, LWD, trailing vegetation, detritus and root mats, as well as open sediment. Mineral substrate dominated by pebbles and gravel, with small amounts of bedrock, cobbles, silt and clay. Maximum water depth of 0.2 m in both seasons.		
MarC2	**Permanent pools**	Series of permanent, shallow pools located on the main channel of Marillana Creek, downstream of the confluence with the un-named tributary. Riparian vegetation comprising *Eucalyptus camaldulensis*, *Melaleuca argentea, M. glomerata*, *M. bracteata*, *Acacia ampliceps* and *A. bivenosa*. In-stream habitat comprising submerged charophytes (*Chara* spp.) and emergent (*Typha domingensis* and *Cyperus vaginatus*) macrophyte, detritus, algae, LWD, roots and trailing vegetation. Mineral substrate predominately comprised of pebbles and gravel, with some cobbles and silt also present. The maximum water depth was 0.3 m in the dry and 0.4 m in the wet.		

Site	Habitat	Description	Dry 2020 Site Photo	Wet 2021 Site Photo
MarC3	**Permanent pool**	Long open pool over bedrock. *Melaleuca argentea, M. glomerata* and *Acacia coriacea* subsp. *pendens* over *Schoenoplectus subulatus* and *Eleocharis geniculata* sedges. High amounts of algae present, as well as some submerged macrophyte (*Vallisneria nana*) and charophytes (*Chara* spp.), LWD, detritus, roots and trailing vegetation. Substrate dominated by bedrock. Maximum water depth of 0.6 m in both seasons.		
MarC4	**Small permanent pool**	A small (15 m long, 11 m wide) permanent pool. Riparian vegetation comprising *Eucalyptus camaldulensis*, *Melaleuca argentea* and *M. glomerata*. In-stream habitat comprising submerged macrophyte (*Potamogeton tepperi*) and charophytes (*Chara* spp.), with some algae, detritus, LWD, emergent macrophytes (*Typha domingensis*, *Cyperus vaginatus* and *Schoenoplectus subulatus*) and open sediment. Mineral substrate was heterogenous, comprising bedrock, pebbles, gravel, sand and silt. Maximum water depth of 0.7 m recorded in the dry and 0.4 m in the wet. The highly invasive weed, awnless barnyard grass (*Echinochloa colona*) was present.		

Site	Habitat	Description	Dry 2020 Site Photo	Wet 2021 Site Photo
MarC5	**Permanent pool**	Series of permanent, shallow pools. Riparian vegetation comprising *Eucalyptus camaldulensis*, *Melaleuca glomerata* and *Acacia coriaceae* subsp. *pendens*. In-stream habitat predominantly open sediment, with some submerged charophytes (*Chara* spp. and *Nitella* spp.), submerged macrophyte (*Vallisneria nana*), emergent macrophytes (*Typha domingensis*, *Cyperus vaginatus* and *Schoenoplectus subulatus*), detritus, LWD and roots. Mineral substrate dominated by gravel and pebbles, with low amounts of bedrock, cobbles, sand and silt. The maximum water depth recorded was 0.3 m in the dry and 1.8 m in the wet.		
MarC6	**Semi-permanent pool**	Semi-permanent pool colloquially referred to as Flat Rocks (Streamtec, 2004). Likely was permanent historically. Most downstream site on Marillana Creek within the Study Area. Though located upstream of current mining operations, this site is thought to be impacted by drawdown from the nearby BHP WAIO Yandi operations (WRM, 2018). Riparian vegetation comprising *Eucalyptus* sp., *Melaleuca glomerata* and *Acacia coriaceae* subsp. *pendens*. In-stream habitat dominated by open sediment and cover from submerged macrophytes (*Potamogeton tepperi* and *Ruppia polycarpa*) and charophytes (*Chara* spp.). Small amounts of detritus, LWD and algae also present. Substrate comprising bedrock and clay, with small amounts of boulders, cobbles, pebbles, gravel and silt. Maximum water depth was 0.15 m in the dry and 1.5 m in the wet.		

Site	Habitat	Description	Dry 2020 Site Photo	Wet 2021 Site Photo
MACREF1	**Permanent pools**	Series of permanent pools and riffles, with the main pool approximately 200 m long and 15 m wide. *Eucalyptus camaldulensis*, *Melaleuca argentea*, *M. glomerata* and *M. bracteata* overstorey, over sedges (*Typha domingensis*, *Schoenoplectus subulatus* and *Cyperus vaginatus*). In-stream habitat comprising submerged macrophyte (*Vallisneria nana*), LWD, detritus, roots and trailing vegetation. Predominantly bedrock substrate, with small amounts of gravel, pebbles and silt. Maximum water depth of 1.3 m in the dry and 1.4 m in the wet.		
MACREF2	**Permanent pools**	Long series of permanent pools and riffles sequences on Marillana Creek, located on upstream of the confluence with the un-named tributary. Riparian vegetation comprising *Eucalyptus camaldulensis*, *E. victrix*, *Melaleuca bracteatea*, and *M. glomerata* as well as several *Acacia* species and shrubs. Complex in-stream habitat comprising submerged macrophyte (*Vallisneria nana*), emergent macrophytes (*Typha domingensis*, *Cyperus vaginatus* and *Schoenoplectus subulatus*), algae, detritus, and LWD. Mineral substrate comprising bedrock, boulders, cobbles, pebbles, gravel, silt and clay. Maximum water depth of 0.6 m in both seasons.		

Site	Habitat	Description	Dry 2020 Site Photo	Wet 2021 Site Photo
WWS	**Spring**	Permanent spring comprising a series of pools and interconnecting riffles. Located within Rio Tinto's HD1 discharge area – surface flows maintained by discharge from spurs. Riparian vegetation comprised *Melaleuca argentea*, *Eucalyptus camaldulensis* and a dense shrub layer. Emergent macrophyte comprising *Typha domingensis*, *Cyperus vaginatus, Schoenoplectus subulatus* and *Eleocharis geniculata*. Fringing *Lobelia arnhemiaca* throughout. The Priority 3 species *Stylidium weeliwolli* was only observed in the dry season, and may have been flushed out during wet season flooding. There was a considerable amount of large woody debris present in the wet, with whole trees and large branches having fallen into the creek during the flood. WWS is a Priority 1 PEC. Maximum water depth was 1.3 m in the dry and 1.1 m in the wet.		
BENS	**Spring**	Second occurrence of the WWS PEC, located upstream on Weeli Wolli Creek. Riparian vegetation consisting of *Eucalyptus camaldulensis* and *Melaleuca argentea* woodland over *Acacia* spp. shrubland, and sparse sedges (*Cyperus vaginatus*). The P3 *Stylidium weeliwolli* fringing on banks during the dry season, but not the wet season. Likely flushed out during the wet season flooding events. Detritus and LWD present in-stream. Mineral substrate dominated by transmissive gravel and pebbles, with some sand, silt, bedrock and boulders. Obvious impacts by cattle, with sedges grazed, and erosion of banks. Maximum water depth of 1.1 m in the dry and 1.6 m in the wet.		

Site	Habitat	Description	Dry 2020 Site Photo	Wet 2021 Site Photo
SS	**Spring**	Permanent spring flowing into a series of pools via a braided channel. Riparian vegetation comprising *Melaleuca argentea* and sedges (*Cyperus vaginatus* and *Eleocharis geliculata*). Submerged macrophyte comprising *Nitella* spp., *Najas marina*, *Vallisneria annua*, *Potamogeton tepperi* and *Ruppia* sp. scattered throughout. The P2 Priority flora (ground creeper *Ipomoea racemigera*) present. Mineral substrate heterogenous, dominated by gravel, pebbles and sand. Disturbances included cattle impacts and introduced vegetation (such as Mexican poppy *Argemone ochroleuca* subsp. *ochroleuca*). Maximum water depth of 2.5 m in the dry and 1.2 m in the wet. This site had undergone considerable change between seasons, with deep pools infilled by mobile sediment, and movement of the main braided channels.		
RW	**Spring**	Permanent groundwater fed pool and riffles. Small series of pools and riffles also located upstream of the main spring. Riparian vegetation comprising *Melaleuca argentea* over *Cyperus vaginatus*. In-stream habitat comprising submerged macrophyte (*Potamogeton tepperi*), detritus, algae, LWD, root mats, and trailing vegetation. Bedrock substrate dominant upstream, with boulders, cobbles, pebbles, gravel, sand and silt present in the main pool. Maximum water depth of 1.8 m in the dry and 4 m in the wet. This site was still in flood at the time of the wet season sampling event, with fast flow and turbid waters.		

4.4 Water Quality

All raw water quality data are provided in Appendix D.

4.4.1 In situ

Electrical conductivity (EC) of surface waters within the Study Area were fresh to slightly brackish. EC ranged from 1,150 µS/cm (at MarC5) to 2,379 µS/cm (at MarC3) in the dry 2020, and 868 µS/cm (at MarC6) to 2,416 µS/cm (at MarC2) in the wet 2021 (Figure 4.1). All sites recorded EC in excess of the ANZG (2018) DGV and most within the Study Area also exceeded the point of ecological stress (~1,500 µS/cm) (Hart *et al.*, 1991). Interestingly, several sites recorded marginally higher EC values in the wet season, including both Study Area (MarC1, MarC2, MarC4 and MarC5) and reference sites (MACREF2, MACREF1 and WWS). This illustrates the permanence of the water in these areas, with limited evapoconcentration occurring during the dry season. MarC6 showed signs of evapoconcentration effects, with considerably higher EC recorded in the dry season.

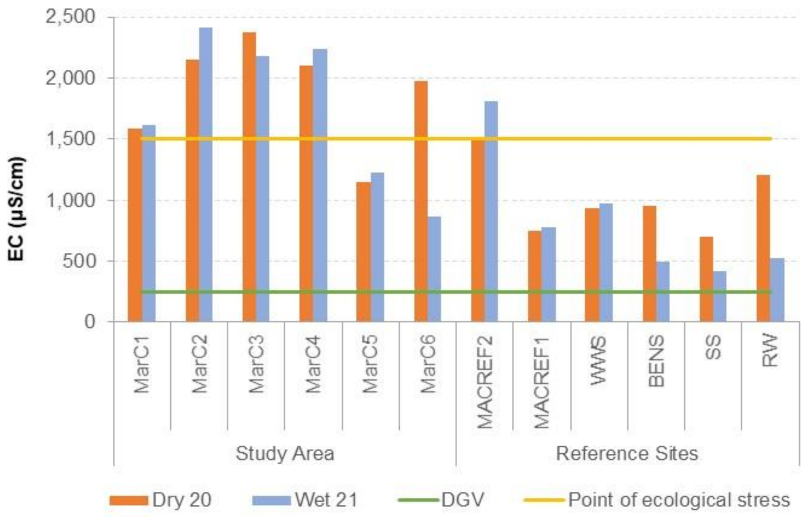


Figure 4.1: Electrical conductivity (EC; µS/cm) recorded from all sites, in comparison to the ANZG (2018) DGV and point of ecological stress.

Dissolved oxygen (DO) concentrations were variable and ranged from 45.1% (at SS) to 182.9% (at MarC6) in the dry 2020, and 33.9% (at MACREF1) to 118.2% (at RW) in the wet 2021 (Figure 4.2). DO recorded from the Study Area was generally lower in the wet season, with most sites recording saturations below the lower DGV at this time. Several reference sites also recorded low DO, in at least one season (Figure 4.2). The higher DO recorded from the Study Area in the dry season may have been related to the lower water levels. Despite several sites recording DO below the lower DGV, in at least one season, no values were below the point of ecological stress (~30%) (Butler & Burrows, 2007). Two sites recorded DO in excess of the upper ANZG (2018) DGV in the dry season, including MarC1 (147.9%) and MarC6 (182.9%). Super-saturated DO at these sites was likely due to shallow water and the high abundance of submerged macrophyte and algae present, and therefore high rates of photosynthesis during the day. MarC1 was also flowing which creates oxygen in the process.

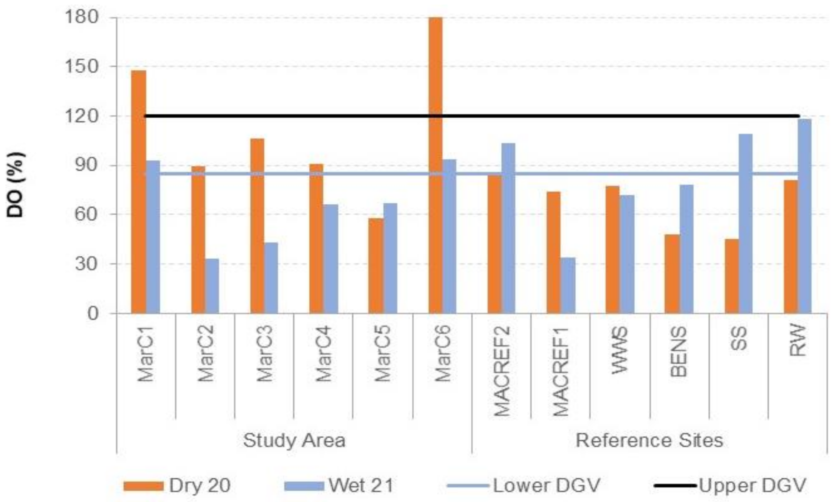


Figure 4.2: Dissolved oxygen (DO; percentage) recorded from all sites, in comparison to the ANZG (2018) upper and lower DGVs.

Surface waters within the Study Area were slightly basic to circum-neutral, with pH ranging from 7.37 (at MarC2 in the dry) to 9.24 (at MarC6 also in the dry). While all reference sites recorded pH within the ANZG (2018) DGVs, several Study Area sites exceeded the upper DGV, in at least one season. Despite this, no pH values were considered to be of ecological concern or out of the ordinary for Pilbara waters. Slightly basic pH is often recorded from Pilbara pools, especially those with some connection to groundwaters.

Turbidity was low and within the DGV at all Study Area and reference sites, indicating high water clarity and light penetration in both seasons. In the dry 2020, turbidity ranged from 0.1 NTU (at RW) to 12.2 (at MarC6), while in the wet 2021, turbidity ranged from <0.1 NTU (at WWS) to 6.3 (at RW).

4.4.2 Ionic composition

There was minimal change in ionic dominance of surface waters within the Study Area between site and season. Generally, all sites were dominated by sodium (Na) cations and hydrogen carbonate (HCO_3) anions. Exceptions to this were MarC1 and MarC6. The former was dominated by Na and chloride (Cl) in the dry 2020, and calcium (Ca) and HCO_3 in the wet. The latter was dominated by Na and Cl in both seasons. Of the other sites within the Study Area, it is likely that most sites receive some contribution from groundwater inputs. Generally, there was a longitudinal decrease in Ca concentration along Marillana Creek. Reference sites MACREF1 and MACREF2 were dominated by Na and Cl. Of the remaining reference sites, SS (wet 2021), WWS (both seasons) and BENS (both seasons) were dominated by Ca and HCO_3. In the dry 2020, SS was dominated by Na and HCO3, as was RW (in both seasons).

Alkalinity measures the capacity of the water to resist sudden changes in pH, i.e., it is the buffering capacity of the water. Alkalinity of less than 20 mg/L is considered low, and the system would have limited ability to buffer against rapid changes in pH. Alkalinity recorded in the current study was generally high, and ranged from 162 mg/L (SS in the wet 2021) to 618 mg/L (MarC2 in the dry 2020). The lowest alkalinity recorded from the Study Area was from MarC6 in the wet 2021 (177 mg/L), although this value was still high in comparison to the 20 mg/L threshold. This suggests waters within the Study Area have a good buffering capacity.

4.4.3 Nutrients

Nitrogen nutrient concentrations within the Study Area were generally low. Nitrogen ammonia (N_NH$_3$) concentrations were below the limit of detection (LOD; i.e. < 0.01 mg/L) at all sites in the dry 2020, and in the wet 2021 ranged from below LOD to 0.05 mg/L (at MarC4 and MarC5). All concentrations were well below toxicity DGVs for the protection of 99% of species (Figure 4.3). Similarly, nitrogen nitrate (N_NO$_3$) concentrations within the Study Area were low, and below the LOD at all sites in both seasons. One reference site recorded nitrate concentrations in excess of the 99% toxicity DGV[4]; RW (1.73 mg/L) in the dry 2020 (Figure 4.3). This concentration was within the 95% toxicity DGV.

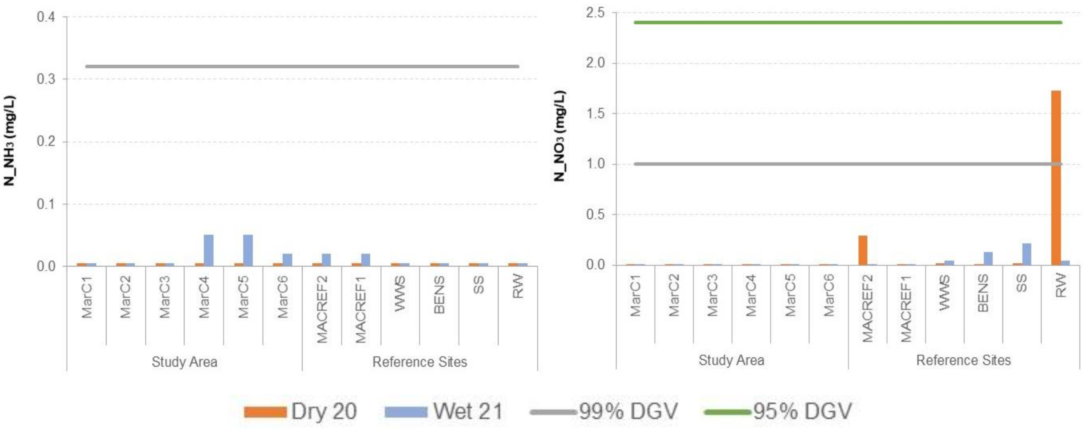


Figure 4.3: Ammonia (N_NH$_3$; left) and nitrate (N_NO$_3$; right) concentrations recorded from each site (mg/L), in comparison to ANZG (2018) default toxicity GVs. NB: y-axis scales are different for each analyte.

As nitrate generally comprises the largest portion of nitrogen oxide (N_NOx) concentrations, with negligible contribution by nitrite, N_NOx concentrations were similarly variable, i.e., ranged from below LODs to 1.73 mg/L (at RW in the dry 2020, Figure 4.4). All N_NOx concentrations recorded from the Study Area were below the eutrophication DGV. Reference sites recorded some exceedances of the eutrophication DGV, with N_NOx concentrations being elevated at MACREF2, WWS, SS and RW in the dry 2020, and WWS, BENS, SS and RW in the wet 2021 (Figure 4.4).

[4] There is no current, available toxicity DGV for N_NO$_3$. Historic ANZECC & ARMCANZ (2000) GVs were found to be erroneous and notably low/conservative (ANZG, 2018). It was anticipated that values would be updated in the recent online, interactive version of the ANZECC guidelines (ANZG, 2018), however this has not been the case. In the absence of updated ANZECC DGVs for N_NO$_3$, ANZG (2018) suggest referring to the current New Zealand nitrate toxicity guidelines, specifically the 'Grading' GVs published in the '*Updating Nitrate Toxicity Effects on Freshwater Aquatic Species*' report (NIWA, 2013).

Concentrations of total nitrogen (total N) in the Study Area ranged from 0.07 mg/L (at MarC1 and MarC2 in the wet 2021) to 2.02 mg/L (at MarC6 in the dry 2020; Figure 4.4). Most Study Area sites exceeded the total N eutrophication DGV in at least one season, although most exceedances were marginal. Comparably high concentrations were also recorded from reference sites MACREF2 (0.35 mg/L), RW (1.63 mg/L) in the dry 2020, and SS (0.46 mg/L) in the wet 2021.Only one site within the Study Area (MarC6 in the dry 2020) recorded total N notably in excess of the DGV. At this site, total N was more than six times the DGV.

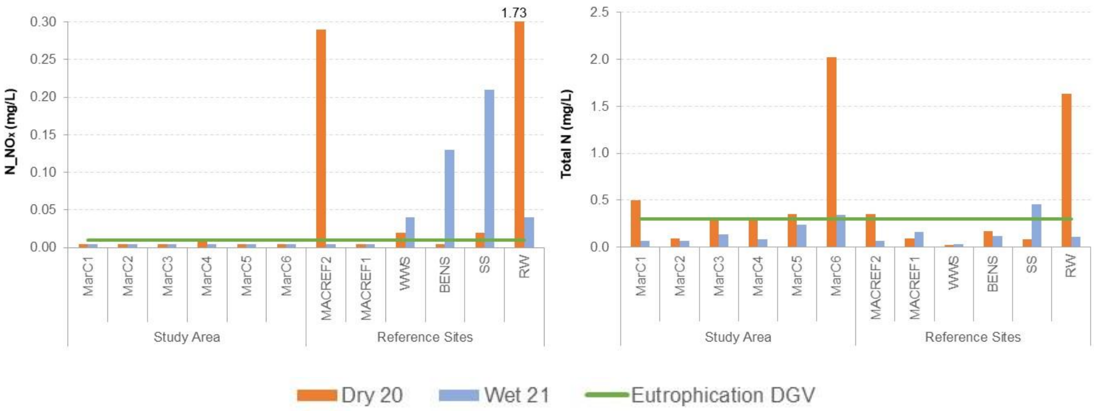


Figure 4.4: Nitrogen oxide (N_NOx; left) and total nitrogen (TN; right) concentrations recorded from each site (mg/L), in comparison to ANZG (2018) eutrophication DGVs. NB: y-axis scales are different for each analyte.

Total phosphorus (total P) was high across all Study Area and reference sites (Figure 4.5). Within the Study Area, concentrations ranged from 0.03 mg/L (at MarC3 and MarC4) to 0.16 mg/L (at MarC6) in the dry 2020, and 0.02 mg/L (at MarC6) to 0.035 mg/L (at MarC2) in the wet 2021. All sites, including reference sites, recorded elevated TP concentrations in excess of the eutrophication GV, in both seasons. Concentrations at MarC6 were notably high in the dry 2020, with total P being more than 16 times the DGV. This reduced to around two times the DGV in the wet 2021, following wet season flushing (Figure 4.5).

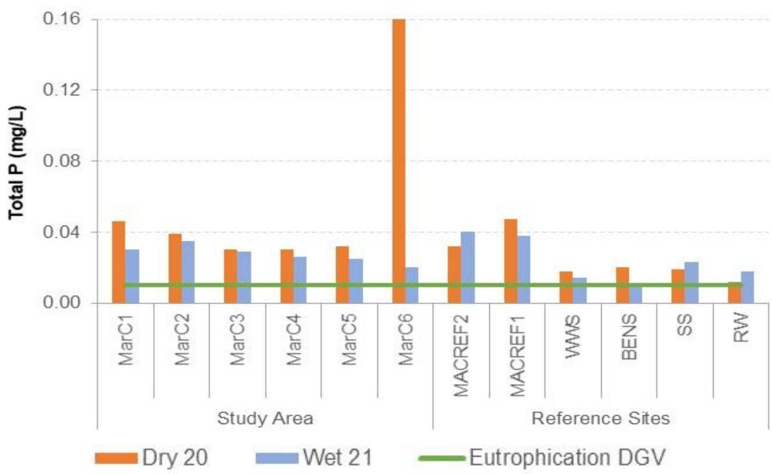


Figure 4.5: Total phosphorus (TP) concentrations recorded from each site (mg/L), in comparison to the ANZG (2018) eutrophication DGV.

4.4.4 Dissolved metals

Dissolved metal concentrations within the Study Area were generally low, with many analytes recording concentrations below LODs at most, if not all sites in both seasons (i.e., dissolved aluminium, cadmium, nickel, lead, selenium, and zinc). However, several dissolved metals wererecorded in concentrations greater than toxicity DGVs at some sites (Figure 4.6). Elevated dissolved metals recorded from the Study Area included:

- Dissolved boron (dB) concentrations exceeded the 95% toxicity DGV at MarC2, MarC3 and MarC4. dB was also elevated in comparison to the 95% DGV at reference site MACREF2 in both seasons, and the 99% DGV at all sites except BENS and SS.
- Dissolved copper (dCu) was in excess of the 95% toxicity DGV at MarC6 in the dry 2020. All other sites were within DGVs, including the 99% DGV.
- Dissolved iron (dFe) at MarC2 was greater than the interim indicative working level[5] provided in the ANZG (2018), in both seasons. dFe concentrations at all other sites were below the interim indicative working level. Generally, higher dFe concentrations were recorded from the Study Area, in comparison to reference sites (Figure 4.6).

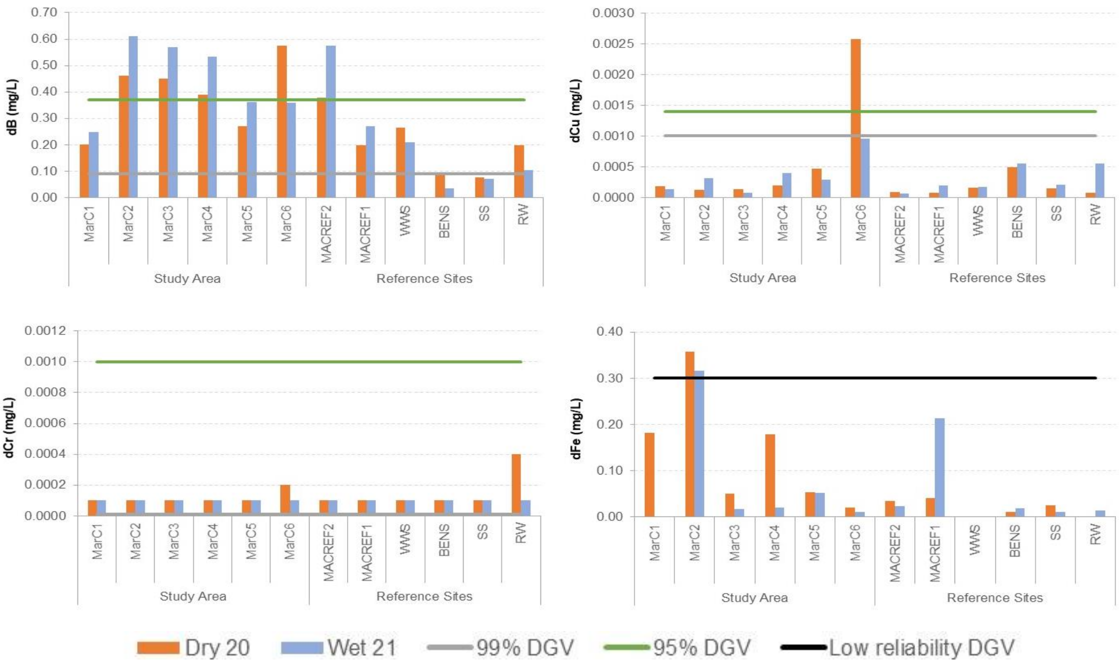


Figure 4.6: Concentrations of selected dissolved metals recorded from each site, in comparison to the ANZG (2018) default toxicity GVs, including dB, dCu, dCr and dFe. NB: y-axis scales are different for each analyte.

Dissolved chromium (dCr) could not be compared against the 99% DGV as the LOD (< 0.0002 mg/L) was higher than the DGV (0.00001 mg/L); however, no dCr concentrations were in excess of the 95% toxicity DGV (Figure 4.6).

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[5] ANZG (2018) had insufficient toxicity data with which to derive a reliable GV for dFe, and instead deferred to the current Canadian guideline of 0.30 mg/L. This was provided as an interim indicative working level, with further work required to establish a concentration appropriate for Australian waters.

4.5 Wetland flora

4.5.1 Taxa composition and richness

A total of12 wetland flora taxa were recorded from the Study Area, including five emergent macrophyte taxa and seven submerged macrophytes (Table 4.6). A further three submerged macrophyte taxa were recorded from reference sites (Table 4.6). Other riparian vegetation taxa recorded from the Study Area, included GDV species such as *Eucalyptus camaldulensis* and *Melaleuca argentea*, as well as *Melaleuca glomerata*, *Melaleuca bracteata*, *Acacia* species, and various herbs, shrubs, and grasses (Table 4.6).

Emergent macrophytes recorded from the Study Area included *Cyperus ixiocarpus*, *Cyperus vaginatus*, *Eleocharis geniculata*, *Schoenoplectus subulatus,* and *Typha domingensis* (Table 4.6). Emergent macrophytes were present at all sites during the dry season, reflecting the presence of permanent water. The greatest diversity of emergent macropytes was four taxa, which was recorded from two Study Area sites (MarC1 and MarC3) and three reference sites (MACREF2, WWS and SS;Table 4.6).

Submerged macrophytes recorded from the Study Area comprised *Naja tenuifolia*, *Vallisneria nana*, *Potamogeton tepperi*, *Potomogeton tricarinatus*, *Ruppia polycarpa*, *Chara* sp., and *Nitella* sp. (Table 4.6). Taxonomic limitations for Pilbara species of *Chara* and *Nitella* precluded identification to species. Submerged macrophytes were recorded from all Study Area sites and three of the six reference sites (Table 4.6). Reference site SS recorded the greatest diversity of submerged macrophytes (six taxa), followed by MarC4 and MarC6 (both with five taxa).

4.5.2 Conservation significant flora

Two species of conservation significance were recorded during the current study, neither of which were recorded from the Study Area. Both annual herb species, *Ipomoea racemigera* and *Stylidium weeliwolli*, are listed as DBCA Priority Species, P2 and P3, respectively. The former was recorded from SS and the later from WWS. *Stylidium weeliwolli* is considered to be an indicator of soil moisture or semi-permanent to permanent surface water availability (Rio Tinto, 2020).

4.5.3 Introduced flora

Three introduced species, one grass (**Echinochloa colona*) and two herbs (**Erigeron bonariensis* and **Flaveria trinervia*), were recorded from the Study Area. Three additional introduced species (**Argemone ochroleuca* subsp. o*chroleuca, *Bidens bipinnata, and *Setaria verticillata*) were collected from reference sites. None of these species are listed as Weeds of National Significance (WoNS), however **Echinochloa colona, *Argemone ochroleuca* subsp. o*chroleuca, *Bidens bipinnata, and *Setaria verticillata* are all considered to be highly invasive and able to establish rapidly (DBCA, 2013). Additionally, **Echinochloa colona* and **Setaria verticillata* are considered to have a high ecological impact on Pilbara ecosystems (DBCA, 2013).

Table 4.6: Flora taxa recorded during the current study. NB: D = recorded in dry season, W = recorded in wet season.

Class/Order	Family	Lowest taxon	Study Area						Reference Sites					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF1	MACREF2	WWS	BENS	RW	SS
CHLOROPHYTA														
CHAROPHYCEAE														
Charales	**Characeae**	*Chara* spp.↓	DW	DW	DW	D	DW	DW	W					
		Nitella spp.↓					D							D
PLANTAE														
MAGNOLIOPSIDA														
Asterales	**Asteraceae**	**Bidens bipinnata*							W					
		*Blumea tenella^*											D	
		**Erigeron bonariensis*		W					W					
		**Flaveria trinervia*				D								
		*Pluchea dentex^*	W	W	DW	W	DW	DW	D	W				
	Campanulaceae	*Lobelia arnhemiaca^*							D		DW			
	Stylidiaceae	*Stylidium weeliwolli^* (P3)									D	D		
Brassicales	**Cleomaceae**	*Arivela viscosa*	W							W				
Fabales	**Fabaceae**	*Acacia ampliceps*	W	DW			W			D				
		Acacia bivenosa		DW					D					
		Acacia colei var. *colei*							W					
		Acacia coriacea subsp. *pendens^*	W		DW		DW	DW	DW	D				
		Acacia pyrifolia var. *pyrifolia*							D					
		Acacia tumida var. *pilbarensis*	W						D	DW				
		Crotalaria medicaginea var. *neglecta*							W					
		Senna artemisioides subsp. *filifolia*						D						
		Tephrosia rosea var. Fortescue creeks (M.I.H. Brooker 2186)					D		DW					
		*Vigna lanceolata^*							DW					
	Surianaceae	*Stylobasium spathulatum*							W					
Gentianales	**Gentianaceae**	*Schenkia clementii*											D	
Lamiales	**Lamiaceae**	*Clerodendrum floribundum*												
	Plantaginaceae	*Stemodia grossa*	D		DW						D			
		Stemodia viscosa	W	W			W							D
Laurales	**Lauraceae**	*Cassytha filiformis*									D			
Malpighiales	**Euphorbiaceae**	*Euphorbia* sp.								W				
	Phyllanthaceae	*Phyllanthus maderaspatensis*					W							
Malvales	**Malvaceae**	*Androcalva luteiflora*								DW	D			
		*Corchorus crozophorifolius^*	W		DW		DW			W				
		Gossypium robinsonii		W					W	DW				
Myrtales	**Lythraceae**	*Ammannia baccifera^*			DW	DW								D
	Myrtaceae	*Eucalyptus* sp.	W	W			W	DW	W	DW				
		*Eucalyptus camaldulensis^*	DW	DW		DW	DW	DW	DW	DW	DW	DW		
		*Melaleuca argentea^*	DW	DW	DW	DW		DW	DW		DW	DW	DW	DW
		*Melaleuca bracteata^^*	DW	DW				W	DW	DW				
		*Melaleuca glomerata^*	DW	DW	DW	DW	DW	DW	DW	DW				
Ranunculales	**Papaveraceae**	**Argemone ochroleuca* subsp. *ochroleuca*												D
Rosales	**Moraceae**	*Ficus brachypoda*							DW					

Class/Order	Family	Lowest taxon	Study Area						Reference Sites					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF1	MACREF2	WWS	BENS	RW	SS
Santalales	**Santalaceae**	*Santalum lanceolatum*							DW					
Sapindales	**Sapindaceae**	*Atalaya hemiglauca*		W						D				
Solanales	**Convolvulaceae**	*Ipomoea racemigera* (P2)												D
LILIOPSIDA														
Alismatales	**Hydrocharitaceae**	*Najas marina*↓												D
		Najas tenuifolia↓				W	W	W						
		Vallisneria annua↓												D
		Vallisneria nana↓			DW	W	DW	W	DW	DW				W
	Potamogetonaceae	*Potamogeton tepperi*↓				D		DW						DW
		Potamogeton tricarinatus↓				W								
	Ruppiaceae	*Ruppia polycarpa*↓						D						
		Ruppia sp.↓												D
Poales	**Cyperaceae**	*Cyperus ixiocarpus*^	W											
		Cyperus vaginatus^	DW	DW	DW	DW	DW	D	DW	D	DW	DW	D	DW
		Eleocharis geniculata^	DW		DW					DW	D		DW	DW
		Schoenoplectus subulatus^		W	DW	DW		DW	DW	D	DW			DW
	Poaceae	Poaceae sp.								D				
		Chrysopogon fallax							D					
		**Echinochloa colona*				W								
		Enteropogon ramosus							W					
		Eragrostis tenellula				W				DW	D			
		Eriachne mucronata							D					
		Eulalia aurea	W					W						
		Imperata cylindrica^							D					
		**Setaria verticillata*							W					
		Sorghum plumosum						W		W				
		Themeda triandra							DW		D			
	Typhaceae	*Typha domingensis*^	DW	DW	W	W	W	DW	DW	DW	DW			DW
		Taxa richness	**19**	**16**	**13**	**16**	**16**	**18**	**32**	**22**	**13**	**4**	**5**	**15**

* Introduced species
(P2/P3) Declared rare flora
^ Associated with creeks and/or sub-perennial surface water
^^ Seasonal wet areas, claypans and rivers
↓ submerged macrophyte

4.5.4 Flora comparison with previous studies

Data on wetland vegetation of the Pilbara is limited, with varied sampling effort and taxonomic resolution across studies. However, wetland flora was sampled as part of the PBS, with a paper discussing conservation significance and distribution information due for publication soon (Mike Lyons, DBCA, unpub. data). To compare species lists with the current study, the DBCA kindly provided Biologic with data from the PBS for sites in the East Pilbara, relatively close to the Study Area.

Wetland flora taxa richness recorded from the Study Area was high when compared to nearby sites sampled during the PBS (Figure 4.7). This was particularly the case at MarC4 and MarC6, with richness at these sites being greater than all PBS sites, including the Weeli Wolli Spring PEC. Even the lowest richness from the Study Area was at least comparable (Kalgan Pool), if not higher than the PBS (Homestead Creek; Figure 4.7). The high richness of wetland flora recorded from the Study Area highlights the persistence of water in this area.

There was a notable reduction in wetland flora richness at WWS between the PBS and current survey. However, this area is currently impacted by dewatering and discharge operations from Rio Tinto's HD1 (EPA, 2018b), as well as more recently being affected by the introduction of the invasive redclaw (which feed on submerged macrophytes) (Biologic, 2020c; Marufu *et al.*, 2018; Pinder *et al.*, 2019). It should also be noted that site locations at Weeli Wolli Spring differed slightly between surveys, with the PBS site being located approximately 660 m downstream of the WWS site sampled during the current survey.

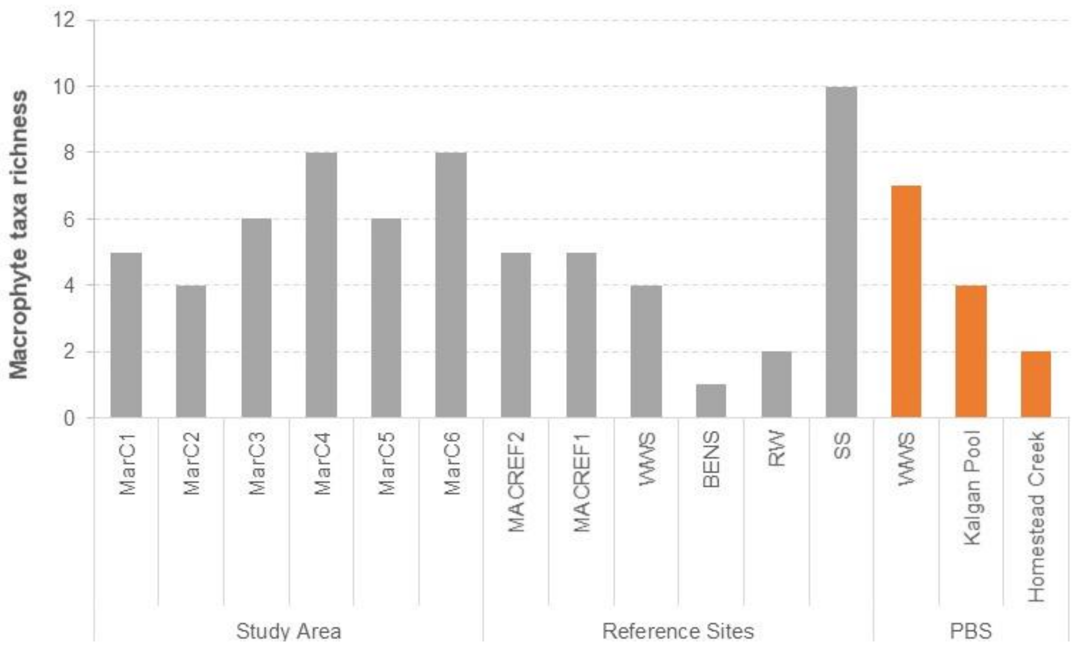

Figure 4.7: Wetland flora richness (emergent and submerged macrophytes) recorded during the current study (dry and wet seasons combined), in comparison to nearby PBS sites: Homestead Creek headwaters (January 2006), Kalgan Pool (September 2004 and April 2005) and Weeli Wolli Spring (September 2003 and May 2005; Mike Lyons, unpub. data).

4.6 Zooplankton

4.6.1 Taxa composition and richness

A total of 77 zooplankton taxa[6] were recorded from the Study Area, comprising five Protista, 39 Rotifera, nine Maxillopoda (Copepoda), seven Cladocera (water fleas) and 17 Ostracoda (seed shrimp) (see Appendix E for a full taxonomic list).

Zooplankton richness ranged from ten (at MarC6) to 24 (at MarC1) in the dry 2020, and from two (at WWS) to 29 in the wet (at MarC1; Table 4.8). In general, richness recorded from the Study Area was comparable to, if not slightly higher than, reference sites. MarC6 recorded a large seasonal variation in zooplankton taxa richness, with considerably greater richness recorded in the wet season, when the pool was considerably larger and more habitat was available (Table 4.8). Richness at several reference sites was lower in the wet season. This was generally the case for all sites which were either still in flood at the time of sampling or were still showing recent signs of flooding (i.e., WWS, RW, and SS).

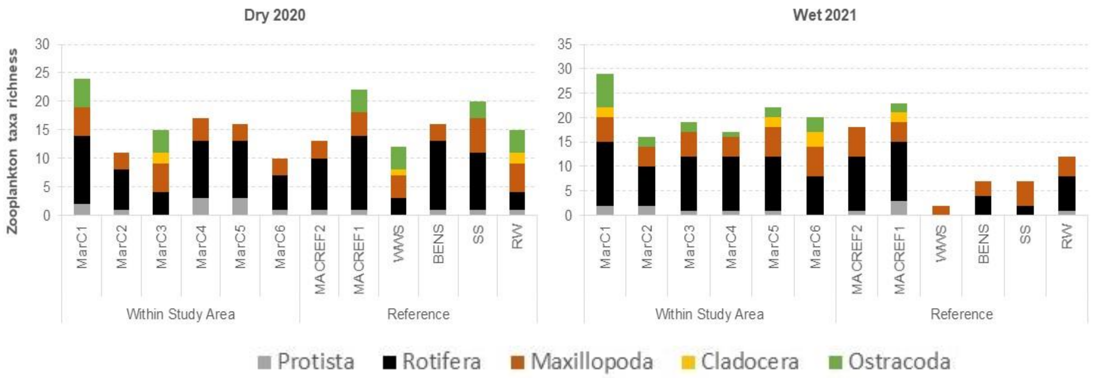

Figure 4.8: Zooplankton taxa richness recorded from each site in the dry 2020 (left) and wet 2021 (right).

Zooplankton composition was dominated by rotifers at most sites, in both seasons, generally followed by Maxillopoda (copepods; Figure 4.8). Diversity of Cladocera was low across all sites, with some sites recording no individuals from this group (Figure 4.8).

Ostracod molecular results

Several ostracod specimens underwent genetic sequencing as part of Biologic's ostracod molecular studies for BHP (Biologic, 2021). Morphological identification of Pilbara ostracods is complicated by a lack of taxonomy and suitable keys, variation within species, minor morphological differences between species, and developmental differences. There are known similarities in carapace morphology between different species within similar hydrogeological settings, for example (Reeves *et al.*, 2007). Therefore, undertaking molecular sequencing in

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[6] As not all specimens could be identified to species due to immaturity, damage, unknown or unresolved taxonomy and/or a lack of suitable keys, taxa refers to the lowest level of identification possible (generally genus).

conjunction with morphological taxonomy is required to identify Pilbara ostracods more accurately, and determine species' distributions with any confidence.

Molecular analysis of ostracods revealed several OTUs with relatively broad distributions.

Candonidae `sp. Biologic-OSTR009`

Molecular analyses found that ostracod specimens collected from surface waters of MarC1 and MarC2 morphologically identified as *Candonopsis tenuis* did not genetically match any described species in the available database (there are no sequences available for *C. tenuis*), but fell into a group of sequences that included other Candonidae species (Biologic, 2021). As such, the family identification was retained, and the taxon from the Study Area was assigned a new OTU; Candonidae `sp. Biologic-OSTR009`. This taxon was 19% divergent from other ostracod specimens sequenced from Afghan Spring and Munjina Creek which were also morphologically identified as *C. tenuis*. The collection of Candonidae `sp. Biologic-OSTR009` in this study constitutes the first record of this OTU. However, since this time, Biologic has recorded this OTU from various locations including sites within the Nullagine River system and Fortescue River catchment. It appears to have a wide distribution throughout the Pilbara. Candonidae `sp. Biologic-OSTR009` was also recorded from the hyporheos of MarC1.

Bennelongia tirigie

The MarC1 specimen identified morphologically as *Limnocythere dorsosicula* by the WA ostracod taxonomist, matched specimens from the formal description of *Bennelongia tirigie*, described in Martens *et al.* (2015) (Biologic, 2021). Juvenile *Bennelongia* can appear to be morphologically similar to *Limnocythere*. *Bennelongia tirigie* is found on the Onslow Coast, Carnarvon area, and just north of Perth (Martens *et al.*, 2015).

Cypridopsis `sp. Biologic-OSTR011`

Specimens morphologically identified as belonging to the genus *Cypridopsis* formed an OTU with sequences from Cenote Yumku, Yucatán (MF076736), and from Pond, Chetumal, Quintana Roo (MF076735, Macario-González *et al.*, 2018). The OTU also included a sequence identified as *Cypridopsis vidua* (KP063117), from a Chinese language publication that could not be translated (Ma *et al.*, 2016), and so the sampling location is unknown, but assumed to be in China. Other sequences of *Cypridopsis vidua* (from the Barcoding of Life website) are ~20% divergent from this lineage. In the absense of a clear identification, we have given this OTU a new name; *Cypridopsis* `sp. Biologic-OSTR011`. This OTU is >17% divergent from other sequences in the analysis, with an intraspecific divergence of <3%. *Cypridopsis* `sp. Biologic-OSTR011` was recorded from reference site MACREF1 (located on a tributary of Yandicoogina Creek).

Cyprididae `sp. Biologic-OSTR006`

Specimens identified as *Stenocypris malcolmsoni*, *Ilyodromus* sp., and *Stenocypris major* all formed a single OTU with GenBank sequences GU070914 and MH937424. GenBank sequence GU070914 is from South Korea, while the MH937424 was collected from India and morphologically identified as a cypridid, *Stenocypris hislopi* (Shinde *et al.*, 2014). The identification of *Ilyodromus* is most likely a morphological identification error. There is one recognised species of *Stenocypris* in Australia, which is variably described as either *S. malcolmsoni* or *S. major* (no OTUs are available on GenBank). It's highly likely that Cyprididae `sp. Biologic-OSTR006` OTU represents this widespread species of *Stenocypris*.. During the current study, Cyprididae `sp. Biologic-OSTR006` was recorded from reference sites, including SS and RW (on the Davis River), and MACREF1 (tributary of Yandicoogina Creek). It has also been recorded previously by Biologic, from Munjina Creek (MUNJE) (Biologic, 2020d) and the Angelo River Project Area (Biologic, unpub. data). Cyprididae `sp. Biologic-OSTR006` has been recorded from both surface waters and the hyporheic zone.

4.6.2 Conservation significant zooplankton taxa

Most zooplankton taxa recorded are widely distributed across northern Australia or the world (cosmopolitan species), and none are listed for conservation significance. One known, described species, *Vestalenula marmonieri*, recorded from MarC3 in the dry 2020 is a Pilbara endemic. This species is known to occur widely across the region. Other ostracods of scientific interest, which were assigned OTUs via the genetic study, appear to be restricted based on current information, or have few records currently. Such taxa include *Bennelongia* `sp. Biologic-OSTR026`, Cyprididae `sp. Biologic-OSTR014`, Cyprididae `sp. Biologic-OSTR015` and Cyprididae `sp. Biologic-OSTR019`. Further information regarding these taxa is provided below.

<u>*Bennelongia* `sp. Biologic-OSTR026`</u>

A specimen morphologically identified as *Bennelongia* sp. was genetically nested within the *Bennelongia* genus. However, it did not genetically match any other *Bennelongia* species in the available database, and as such was assigned a new OTU; *Bennelongia* `sp. Biologic-OSTR026`. This OTU was more than 15% different to all other *Bennelongia* species in the available genetic database, including *Bennelongia tirigie*. *Bennelongia* `sp. Biologic-OSTR026` is currently known only from MarC1, but additional molecular work on ostracod specimens collected from BHP samples may increase the known distribution in the future.

<u>Cyprididae `sp. Biologic-OSTR014`</u>

This OTU was found to be gentetically nested within the Cyprididae family, and as such, it's family-level identification was retained. During the current study, Cyprididae `sp. Biologic-OSTR014` was recorded from MarC3, MarC4 and MarC6. It is previously known from the Angelo River Project Area (rehydrate sample; Biologic, unpub. data), located approximately 70 km to the south of the Study Area. Cyprididae `sp. Biologic-OSTR014` was 3-5% divergent from the Angelo River specimens, but more than 20% divergent from all other Cyrididae in the available genetic database.

Cyprididae `sp. Biologic-OSTR015`

Similarly, specimens within this OTU were nested within the family Cyprididae. Cyprididae `sp. Biologic-OSTR015` was recorded from MarC1 in the current study, but has been previously collected from the Angelo River Project Area (rehydrates and hyporheos) by Biologic. Cyprididae `sp. Biologic-OSTR015` was only 3% divergent from the Angelo River specimens, but more than 20% different to all other Cyprididae sequences available in the database.

Cyprididae `sp. Biologic-OSTR019`

During the current study, specimens collected from MarC5 and MarC6 were genetically nested within the Cyprididae but separate to other genera and described species in the available genetic database. These specimens were assigned the OTU Cyprididae `sp. Biologic-OSTR019`. This OTU has been previously recorded by Biologic from two rehydrate samples collected within the Angelo River Project Area (Biologic, unpub. data).

Other species of interest

Other species of interest were recorded from reference sites only and were not found to be present within the Study Area. For example, Candonidae `sp. Biologic-OSTR028`, an ostracod specimen morphologically identified as *Candonopsis* cf. *tenuis* which did not match any sequences in the available database. Molecular analysis showed 21.4% divergence from *Candonopsis* `sp. Biologic-OSTR009`. Candonidae `sp. Biologic-OSTR028` either represents a new species within *Candonopsis*, or a new genus within Candonidae. This OTU was recorded from reference site Running Waters in the Wet 2021.

4.6.3 Zooplankton comparison with previous studies

Zooplankton richness from the Study Area was compared with previous studies detailed in section 4.2 above, for those studies which sampled more than one replicate site within a creek system. Weeli Wolli Creek sites were split into Weeli Wolli Spring (recorded from the historic spring area) and Weeli Wolli Creek (upper Weeli Wolli Creek river pools), to reflect differences in water permanence and hydrology between these two areas; factors which would influence zooplankton assemblages. Two sites could not be included in this analysis due to a lack of replication (MACREF2 and BENS). As detailed in the methods, the dataset was amalgamated, and taxonomy aligned, prior to analysis to ensure any differences in taxonomic knowledge between samplers and years was accounted for.

The Study Area generally recorded average zooplankton richness similar to nearby creek systems (Figure 4.9). Average richness was higher in the wet season in the Study Area, and also in sites in Marillana Creek downstream, and in the semi-permanent river pools in Upper Weeli Wolli Creek (Figure 4.9). In contrast, Yandicoogina Creek, Weeli Wolli Spring and the Davis River all recorded higher average zooplankton richness in the dry, although seasonal variation was notably low in both the Study Area and Yandicoogina Creek (Figure 4.9). The large standard error bars reflect the high within-system variability in zooplankton richness. Interestingly, variability within the Study Area was noticeably lower than all other areas except Yandicoogina Creek, in both seasons (Figure 4.9).

Overall, any differences in zooplankton richness between creek (Two-way ANOVA; df = 5, F = 0.94, p = 0.465) and season (df = 1, F = 0.3, p = 0.865) were not significant. There was also no significant interaction between creek and season (df = 5, F = 1.02, p = 0.415).

4.7 Hyporheos fauna

Hyporheic samples were successfully collected from all sites except MarC6 in the dry 2020, and MACREF1 in both seasons. Conditions at the time precluded hyporheic sampling at these sites, particularly the clay sediment at MarC6 and bedrock substrate at MACREF1 impeding access to the hyporheos. Clay sediment, although being highly porous, is not transmissive and has low hydraulic conductivity. Similarly, bedrock substrates pose sampling issues with respect to accessing the hyporheic zone and disconnect surface waters from hyporheic and groundwater environments. As such, neither clay nor bedrock substrates provide interstitial habitat for hyporheos fauna.

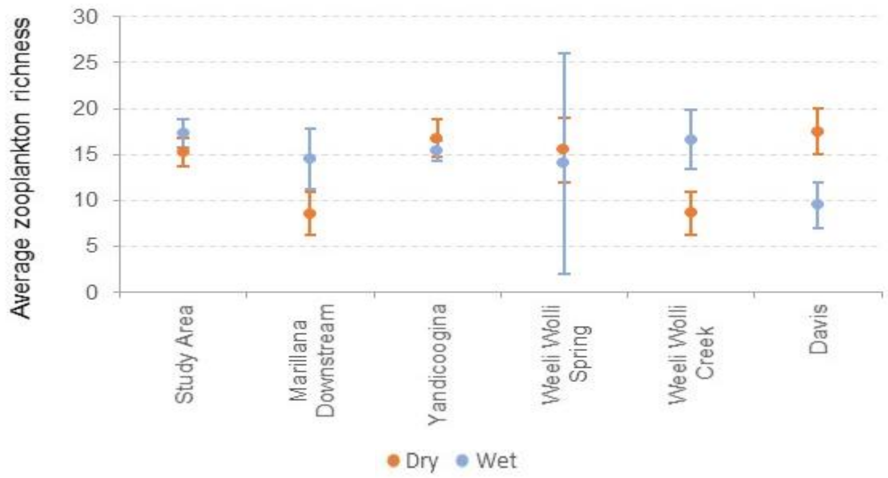


Figure 4.9: Average zooplankton taxa richness (± se) recorded from the Study Area, in comparison to other studies and nearby creek systems, in both seasons.

4.7.1 Taxa composition and richness

A total of 106 invertebrate taxa was recorded from hyporheic zones within the Study Area (see Appendix F for a full taxonomic list). The taxonomic list included Nematoda (roundworms), Platyhelminthes (flatworms), Oligochaeta (aquatic segmented worms; 12 taxa), Hirudinea (leeches), Mollusca (freshwater snails; two taxa), Cladocera (fairy shrimp; one taxa), Ostracoda (seed shrimp; ten taxa), Copepoda (eight taxa), Acarina (water mites; 13), Collembolla (springtails), Coleoptera (beetles; 24), Diptera (two-winged fly larvae; 25), Trichoptera (caddisfly larvae; one), Ephemeroptera (mayfly larvae; three), Hemiptera (true bugs; one), Lepidoptera (moth larvae; one), and Odonata (dragonflies; one). Just over half of these taxa were stygoxenes (61%) and do not have specialised adaptations for life in groundwater habitats. These taxa were recorded from the hyporheic zone 'by chance' but can actively seek out this habitat as a refuge during times of drought or flood. Hyporheos fauna, comprising styogbites, permanent hyporheos stygophiles, occasional hyporheos stygophiles and possible hyporheic taxa, made up the remaining 39% of taxa collected. Of these, a total of 11% are directly dependent on groundwater for their persistence (i.e., stygobites and permanent hyporheos stygophiles). This result is consistent with other Pilbara studies, where generally less than 20% of invertebrate taxa recorded from hyporheic samples are totally reliant on groundwater (Halse *et al.*, 2002). The percentage of stygobitic fauna recorded from hyporheic samples within the Study Area was greater (8%) than that reported by Halse *et al.* (2002) (5% stygobitic fauna).

Hyporheos fauna recorded from the Study Area included:

<u>Stygobites:</u>

- ostracods *Candonopsis tenuis*, *Cypridopsis* sp. \`BOS1401\`, *Ilyodromus* sp., and *Vestalenula* sp., and *Gomphodella alexanderi*.
- copepods *Diacyclops humphreysi* s.l., *Elaphoidella* sp. and *Parastenocaris* sp.
- water mite *Wandesia* sp.

<u>Permanent hyporheos stygophiles:</u>

- water mites *Rutacarus* sp. and *Guineaxonopsis* sp.
- ostracod *Limnocythere dorsicula*.

<u>Occasional hyporheos stygophiles:</u>

- oligochaetes *Allonais pectinata*, *Allonais ranauna*, *Dero nivea*, *Pristina aequiseta*, *Pristina longiseta*, and *Pristina jenkinae*
- copepods *Microcyclops varicans*, *Mesocyclops notius* and *Paracyclops intermedius*
- collembola Entomobryoidea sp.
- beetles *Austrolimnius* sp. (L), Hydraenidae sp. (L), *Hydraena* sp., *Limnebius* sp., *Ochthebius* sp. and Scirtidae sp. (L).

Possible hyporheic taxa included higher-level identifications for which taxa may have belonged to a stygal or hyporheos species, and/or OTUs identified through molecular analysis. These include the flat worm Turbellaria sp.; roundworm Nematoda sp.; oligochaetes Naididae sp., Naidinae sp., *Pristina* sp. and *Pristina* nr. *osborni*; the flatworm Turbellaria sp.; juvenile ostracods (Candonidae sp.), *Bennelongia* sp. and *Cypridopsis* sp.; adult ostracods identified via molecular analysis Candonidae \`sp. Biologic-OSTR009\` and Cyprididae \`sp. Biologic-OSTR006\`; the cyclopoid copepod *Paracyclops* sp.; immature or damaged water mites (Acari sp.); beetle larvae (Bidessini sp. and immature Hydrophilidae sp.) and immature Baetid mayflies (Baetidae sp.).

Overall, site invertebrate richness ranged from six (at WWS in the wet 2021) to 46 (at RW in the dry 2020; Figure 4.10). Stygoxenes dominated taxa richness at most sites except those with low overall richness (WWS in the wet 2021). The hyporheic zone of MarC6 and reference site BENS supported no groundwater dependent taxa, in either season[7], although occasional hyporheos stygophiles were present (Figure 4.10). Such taxa take advantage of the protection afforded by the hyporheic zone seasonally, or during early life history stages. The lack of stygobitic taxa recorded from MarC6 was likely influenced by the high percentage of clay substrate present at this site, which impeded access to the hyporheos. The greatest richness of hyporheos taxa (including occasional stygophiles and possible hyporheic taxa) was recorded from reference site RW in the dry 2020 (20 taxa), followed by MarC4 (16 taxa; wet 2021). All Study Area sites located upstream of MarC6 recorded a high richness of hyporheos fauna, especially in the wet season, with 14 taxa recorded from MarC1, 13 from MarC2 and MarC5, and ten from MarC3 in the wet 2021 (Figure 4.10).

[7] The hyporheos of MarC6 was only successfully sampled in the wet 2021.

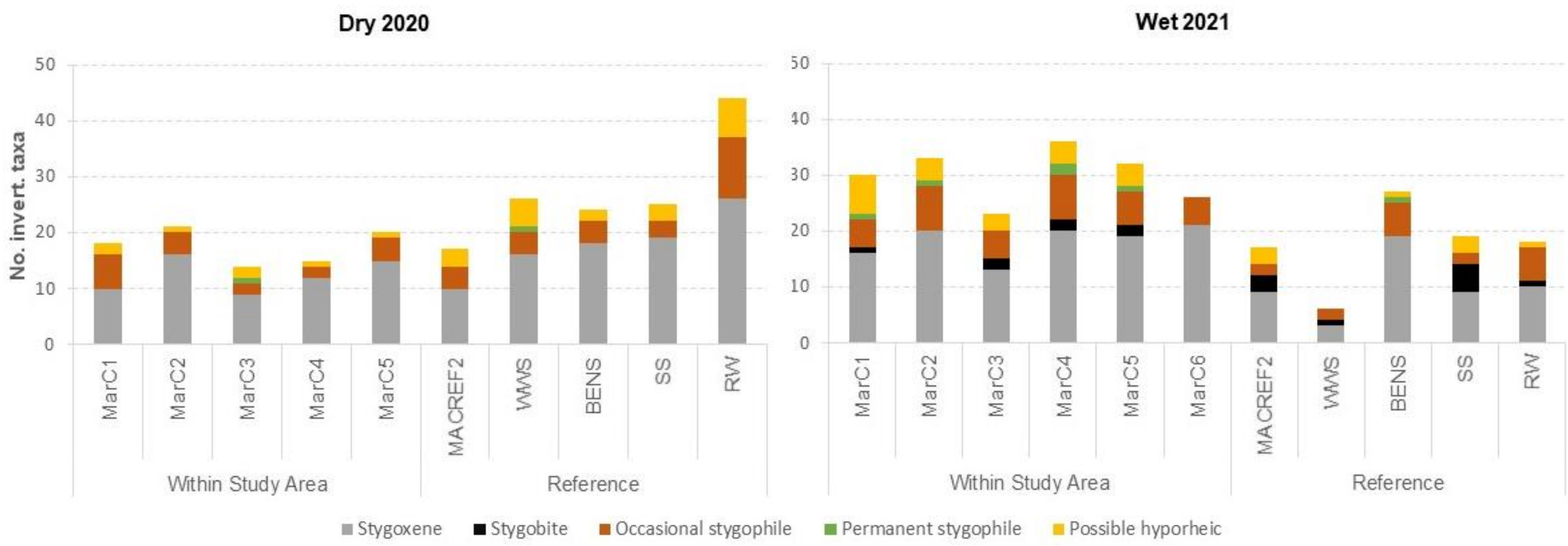


Figure 4.10: Classification of invertebrate taxa recorded from the hyporheic zone, in each season.

The high hyporheos richness recorded from the more upstream Study Area sites suggests a strong connection to groundwaters in this reach. Taxa richness within the Study Area was higher in the wet 2021 compared to the dry 2020. This contrasted with reference sites which generally recorded higher richness in the dry 2020.

4.7.2 Conservation significant hyporheos taxa

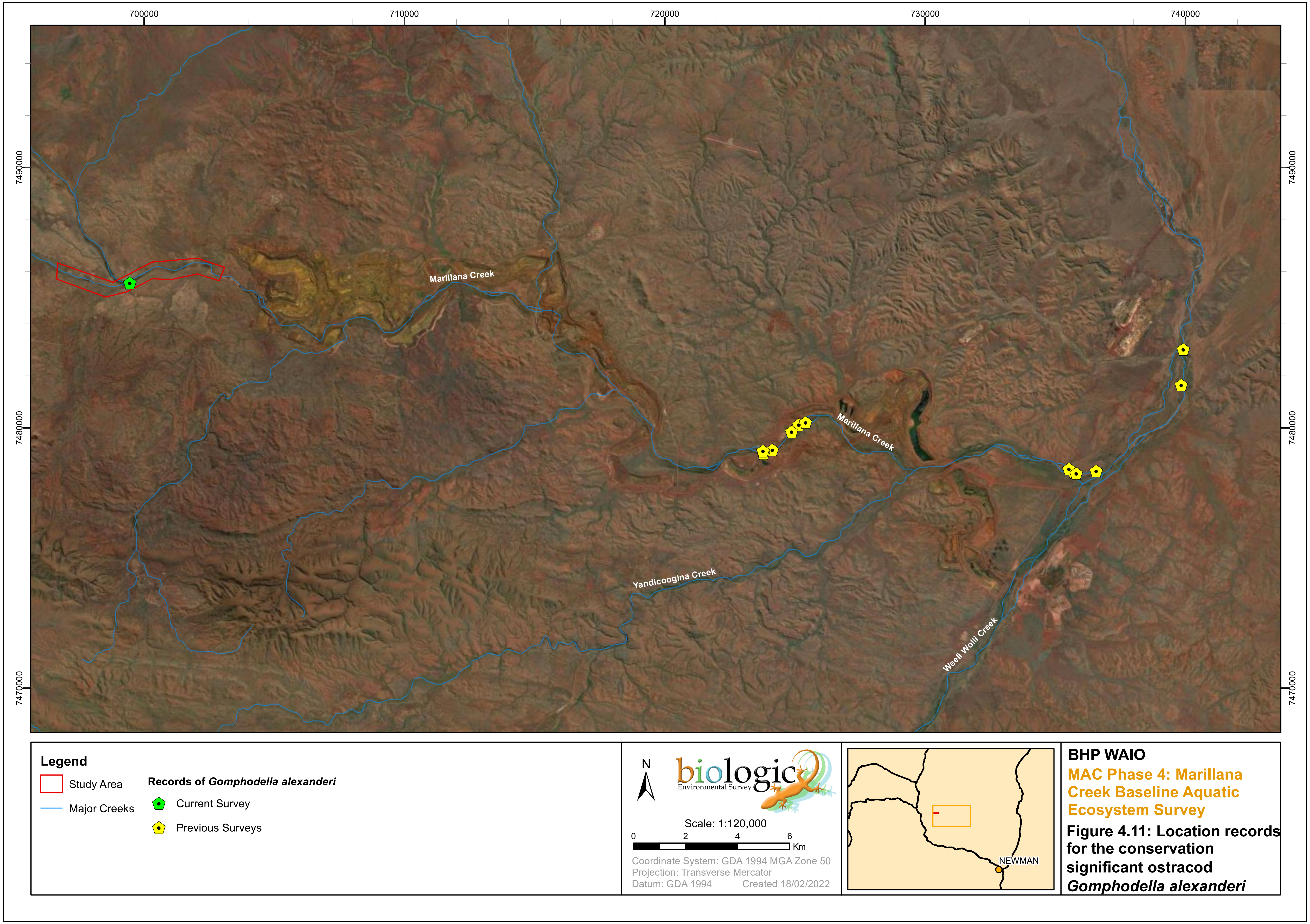
While most of these taxa are generally common and ubiquitous across the Pilbara, a number are of conservation significance and are either locally restricted or rarely collected.

Ostracoda

Data recorded during the PBS indicated that stygobitic ostracod species are generally confined to single sub-catchments, except for *Areacandona scanlonii* and *Gomphodella hirsuta*, which are more widespread. In contrast, surface water ostracods were found to occur across several sub-regions (Halse *et al.*, 2014). Of the stygal ostracods recorded in the current study, one species is restricted to a short range, *Gomphodella alexanderi*. This species was previously known only from interstices of Marillana Creek and groundwater bores at Rio Tinto's Yandi Mine (Karanovic & Humphreys, 2014). It has more recently been recorded from the hyporheos of lower Weeli Wolli Creek (Jess Delaney, unpub. data), and nearby Yandicoogina Creek (Biologic, 2020b) (Figure 4.11). During the dry 2020 survey of the current study, *Gomphodella alexanderi* was recorded from the hyporheos of MarC2 (Figure 4.11). Based on the WAM classification system, *Gomphodella alexanderi* is considered a potential SRE, sub-category data deficient. While their known range is < 10,000 km^2 (or linear range < 100 km), there is insufficient taxonomic and distribution information to confirm SRE status. All known records of this species are in areas either currently impacted by mining activities or those proposed for future mining.

The OTU recorded from MarC1 and MarC2 surface waters, and identified as Candonidae `sp. Biologic-OSTR009` through molecular analyses, was also recorded from the hyporheos of MarC1. As mentioned above (see section 4.6.2), this OTU appears to have a relatively widespread distribution throughout the Pilbara.

The cypridid ostracod *Cypridopsis* sp. `BOS1401` is moderately common, with a disjunct distribution in the Pilbara, and was considered likely to be the same species as that recorded from Yandicoogina Creek (Biologic, 2020b), as well as Meekathara and Mulga East (Stuart Halse, Bennelongia, pers. comm.). *Cypridopsis* sp. `BOS1401` was recorded from the hyporheic zone of MarC1 and MarC2 in the dry 2020.



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.11: Location records for the conservation significant ostracod *Gomphodella alexanderi*

Copepoda

The stygobitic harpacticoid genus *Elaphoidella* is not commonly recorded in the Pilbara. A representative of this genus (*Elaphoidella* sp.) was recorded from MarC4 within the Study Area, as well as reference site SS in the wet 2021. The taxonomy of this genus is not well known, though taxa recorded during the current study is considered likely to represent an undescribed species (Giulia Perina, pers. comms.). Several known morphotypes of *Elaphoidella*, including one described species (*E. humphreysi*) were recorded from bores during the Pilbara Stygofauna Survey (PSS), including bores within the Robe, Fortescue, Ashburton, and de Grey River catchments. The morphotype recorded from the current study is morphologically distinct from *E. humphreysi*, but with no diagnostic information regarding the other Pilbara morphotypes, it is not possible to determine whether *Elaphoidella* sp. has been recorded from elsewhere previously.

The harpacticoid *Parastenocaris* sp. was recorded from MarC5, as well as reference site SS in the wet 2021. *Parastenocaris jane* was recorded during the PBS, from Kangan Pool in the Sherlock catchment (225 km from Study Area), and an Un-named Creek within the Fortescue catchment (228 km from the Study Area). More recently, *P. jane* has also been recorded from Marillana Creek downstream of the Study Area (WRM, 2018). However, it is uncertain whether the individuals from the current study belong to the known species *P. jane*. A number of undescribed *Parastenocaris* morphotypes were also recorded during the PSS, indicating several species exist in the region. It is possible that specimens from the current study could be *Parastenocaris jane*, but due to limitations in taxonomic information this could not be determined.

Acarina

The water mite *Wandesia* sp. is a stygal species which could not be identified to species because the taxonomy of this genus in Western Australia is poorly known and the geographic ranges of the various species have not been determined. All described species of *Wandesia* are known from river interstices in eastern Australia. *Wandesia* sp. was recorded in the current study from Study Area sites MarC1 and MarC5, as well as reference sites WWS and MACREF2 (located on Marillana Creek upstream of the confluence with the tributary). One known, but undescribed species, *Wandesia* sp. P1 (nr *glareosa*), was recorded during the PBS from river pools and springs. It is not known whether the *Wandesia* sp. recorded from the current study is the same as the known morphotype from the PBS. All records during the current study were from sites in relatively close proximity.

The water mite *Guineaxonopsis* sp. was recorded from Study Area sites MarC1, MarC2 and MarC4 during the wet 2021. This genus is not commonly recorded and is poorly understood, with only one species currently described from Tasmania. Two morphotypes are currently known from the Pilbara; *Guineaxonopsis* sp. S1 and *Guineaxonopsis* sp. P1. The former was recorded from Cangan Pool within the Yule catchment (approximately 115 km from the Study Area) during the PBS and several bores during the PSS, including bores from the Robe and

Fortescue River basins, Port Hedland coast and Great Sandy Desert. *Guineaxonopsis* sp. P1 was recorded from Minigarra Creek pools at Woodie Woodie (approximately 259 km from the Study Area) during the PBS, but was not recorded during the PSS. Without having access to specimens from these taxa, it is not possible to determine whether the *Guineaxonopsis* sp. recorded during the current study matches one of the currently known morphotypes or if it is likely new to science. All known species of *Guineaxonopsis* are from interstitial habitats.

The stygal water mite *Rutacarus* sp. was recorded from MarC4 and MarC5 within the Study Area. This genus is poorly known from Western Australia, with two described species from river interstices in eastern Australia. *Rutacarus* sp. was previously recorded during the PBS from a single sampling occasion at Bamboo Spring. It is not possible to determine whether the *Rutacarus* recorded during the current study is the same species as that from Bamboo Spring.

Other species of interest

Other species of interest were recorded from reference sites only and were not found to be present within the Study Area (i.e., Candonidae \`sp. Biologic-OSTR010\`, *Chydaekata* sp. E, Paramelitidae \`sp. Biologic-AMPH024\`, Paramelitidae \`sp. Biologic-AMPH049\`, and *Atopobathynella* sp.). Candonidae \`sp. Biologic-OSTR010\` was identified through molecular sequencing and is currently known only from Yandicoogina and Weeli Wolli Creeks (Biologic, 2021), where it was morphologically identified as the stygal ostracod *Notacandona boultoni*. Sequences for *Notacandona* are currently unavailable for comparison. Although it cannot be stated with certainty that Candonidae \`sp. Biologic-OSTR010\` matches the morphological identification of *Notacandona boultoni,* it is considered likely. It was recorded from reference site WWS during the current study.

The stygal amphipod Paramelitidae \`sp. Biologic-AMPH024\` was also identified through molecular analysis (Biologic, 2020b). This species appears to be restricted to Weeli Wolli Creek (Biologic, 2020b) and was recorded in the current study from WWS. While molecular analysis distinguished this species from Paramelitidae \`sp. Biologic-AMPH023\` (more than 10% divergence), morphological characters are relatively similar and difficult to distinguish. *Chydaekata* sp. E is known from upper Marillana, Yandicoogina and Weeli Wolli Creeks, but was only recorded from reference site WWS in the current study, and not within the Study Area. Another species of stygal amphipod was recorded from reference site SS in the wet 2021; Paramelitidae \`sp. Biologic-AMPH049\`. This OTU was 15% divergent from both Paramelitidae \`sp. Biologic-AMPH023\` and Paramelitidae \`sp. Biologic-AMPH024\`. The OTU recorded from SS in the current study represents an undescribed species which is likely to be restricted to the Davis River. The Paramelitidae sp. recorded from reference RW in the dry 2020 may belong to this same OTU, given it is located on the Davis River, 23 km downstream.

Atopobathynella sp. recorded from the hyporheos of reference site SS could not be identified further due to taxonomic limitations within the group, but the specimen did not appear to match any known Pilbara morphotypes. Many parabathynellid species have been found to be restricted to a single calcrete (Guzik *et al.*, 2008), with more than two-thirds of species having a known range less than 10 km (Bennelongia, 2008).

4.8 Macroinvertebrates

4.8.1 Taxa composition and richness

A total of 295 macroinvertebrate taxa was recorded during the current study, of which 199 was recorded within the Study Area. The macroinvertebrate fauna of the Study Area comprised Hydrozoa (freshwater hydra), Platyhelminthes (flat worms), Nematomorpha (horse hair worms), three gastropod taxa (freshwater snails), Hirudinea (leeches), 13 oligochaete taxa (aquatic segmented worms), Polychaeta (freshwater polychaetes), 24 Acarina (water mites), 61 Coleoptera (beetles), 35 Diptera (two winged flies), nine Ephemeroptera (mayflies), 21 Hemiptera (true bugs), Lepidoptera (moth larvae), 19 Odonata (dragonflies and damselflies) and nine Trichoptera (caddisflies). See Appendix G for the full taxonomic list.

Of the 199 taxa recorded from the Study Area, 71 were singletons and recorded from one site only. More common taxa, recorded from 75% of samples (nine or more samples), included the gastropods *Bullastra vinosa* and *Gyraulus* sp., beetles *Hyphydrus lyratus* and *Hydraena* sp., the biting midges Ceratopogoninae sp. and *Dasyhelea* sp., non-biting midge larvae *Larsia ?albiceps*, *Procladius* sp. and *Tanytarsus* sp., and mayfly *Tasmanocoenis* sp. P/*arcuata*.

Within-site macroinvertebrate diversity was generally high. Greatest richness was recorded from reference site RW in the dry-20 (79 taxa), closely followed by Study Area sites MarC2 in the wet-21 (78 taxa) and MarC5 in the dry (76; Figure 4.12). All Marillana Creek sites recorded high richness, with at least 44 taxa collected. The lowest richness in the Study Area was from the upstream tributary site MarC1 (44 taxa in the dry, and 46 in the wet). Reference site WWS consistently recorded relatively low richness in comparison to other sites sampled in the current study (Figure 4.12). Although this site was classified as a reference for the purposes of this study, it is highly altered due to dewatering and discharge operations at Rio Tinto's HD1 since 2007, as well as being affected by the introduced redclaw more recently.

Most sites were dominated by slow flow and relatively tolerant taxa, i.e., Coleoptera and Diptera. Dominance of Diptera within aquatic macroinvertebrate assemblages of the Pilbara is common (see Pinder *et al.,* 2010). Taxa which require faster flows, such as Lepidoptera and *Cheumatopysche* caddisflies (Trichoptera) were generally restricted to the flowing reference sites, including SS and RW (Figure 4.12). Study Area sites generally recorded a low richness of Trichoptera comparison to reference sites. Interestingly, a notably high richness of Odonata was recorded from the Study Area, particularly MarC5 and MarC6.

Some seasonal variation in taxa richness was apparent, with generally higher richness recorded in the wet-21 across all survey sites (Figure 4.12). Exceptions to this were MarC5 (which recorded 19 fewer taxa in the wet), and reference site RW (34 less taxa in the wet). RW was affected by flooding at the time of sampling in the wet season, with high flows and turbid waters present. It is likely that aquatic macroinvertebrates had been flushed downstream.

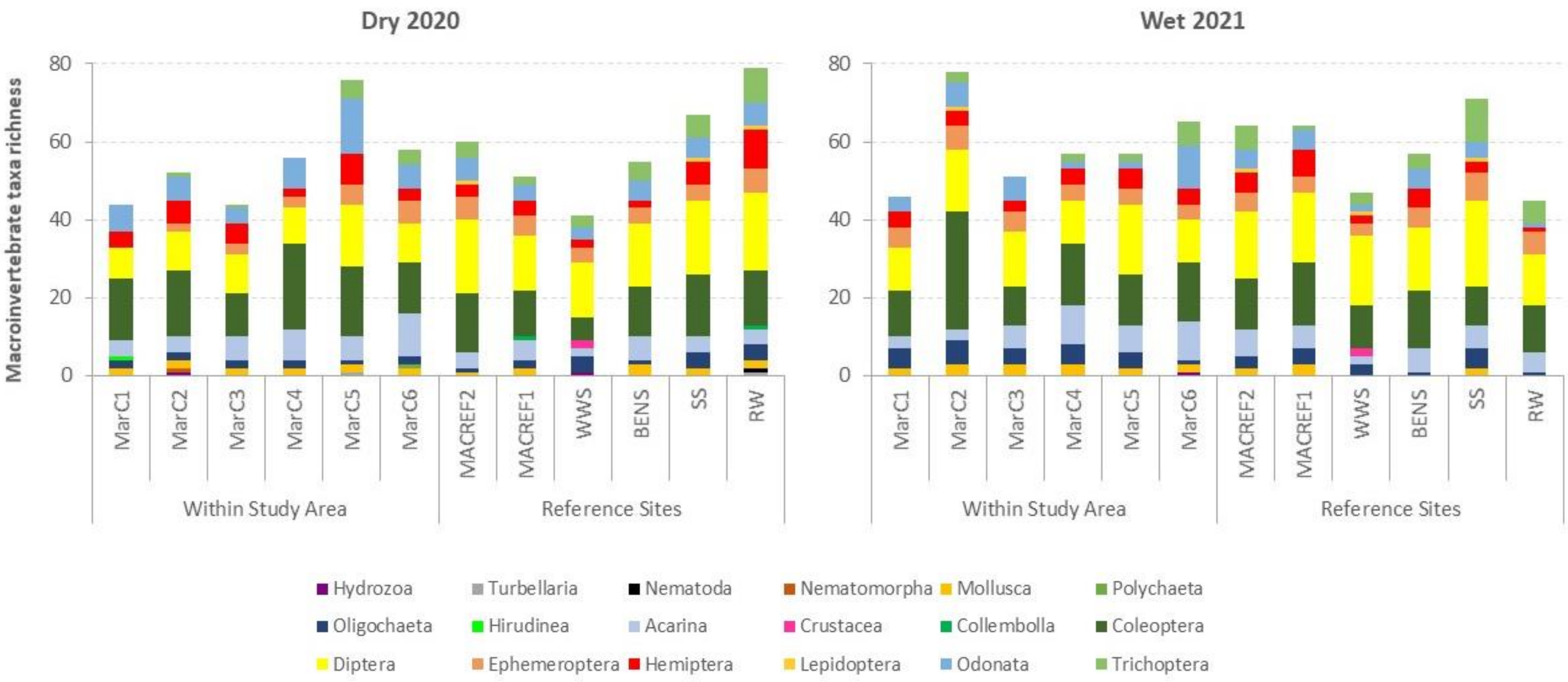


Figure 4.12: Macroinvertebrate taxa richness recorded from each site, in each season.

4.8.2 Conservation significant macroinvertebrate taxa

The vast majority of aquatic macroinvertebrates recorded during the current study were common, ubiquitous species. Excluding taxa which could not be assigned a distribution status due to insufficient information or taxonomy (juveniles/damaged specimens), most remaining taxa had distributions extending across Australia (30%), Northern Australia (17%), or the Australasian region (17%). A total of 12% were cosmopolitan, 7% endemic to Western Australia, 5% found across northern Western Australia, and 1% were introduced. Taxa restricted to the Pilbara region accounted for 12% of the taxa recorded (of those with known distributions). Pilbara endemic taxa were recorded from all sites in at least one season, with the greatest number being recorded from MarC5 and BENS in the dry-20 (six Pilbara endemic taxa each; Figure 4.13). This was closely followed by reference sites MACREF1 (dry) and SS (wet). Interestingly, reference site BENS recorded both the highest richness of Pilbara endemic taxa (in the dry) and the least (in the wet; Figure 4.13).

Figure 4.13: Number of Pilbara endemic macroinvertebrate taxa recorded from each site in each season.

Within the Pilbara endemic fauna recorded from the Study Area were four taxa of further interest; two conservation significant species currently listed on the IUCN Redlist of Threatened Species (*Eurysticta coolawanyah* and *Hemicordulia koomina*), and those with restricted distributions (*Haliplus fortescueensis*) and/or known only from springs or permanent pools of high quality (*Aspidiobates pilbara*).

Odonata

As mentioned previously, the Pilbara pin damselfly *Eurysticta coolawanyah* is currently listed on the IUCN Redlist as Vulnerable (IUCN, 2021). During the current study, it was recorded from MarC5 within the Study Area (dry 2020), and reference sites MACREF2 (dry and wet), MACREF1, WWS, BENS and SS (all in the wet 2021).

The Pilbara emerald, *Hemicordulia koomina*, is also currently listed by the IUCN (2021) as Vulnerable. Despite being recorded from additional locations since its listing, this species is still considered rare and is infrequently collected and rarely recorded. It was recorded from four sites within the Study Area (MarC1, MarC4, MarC5 and MarC6) and reference site BENS. All records were from the dry 2020, with the exception of MarC6 where *H. koomina* was also recorded in the wet 2021.

Acarina

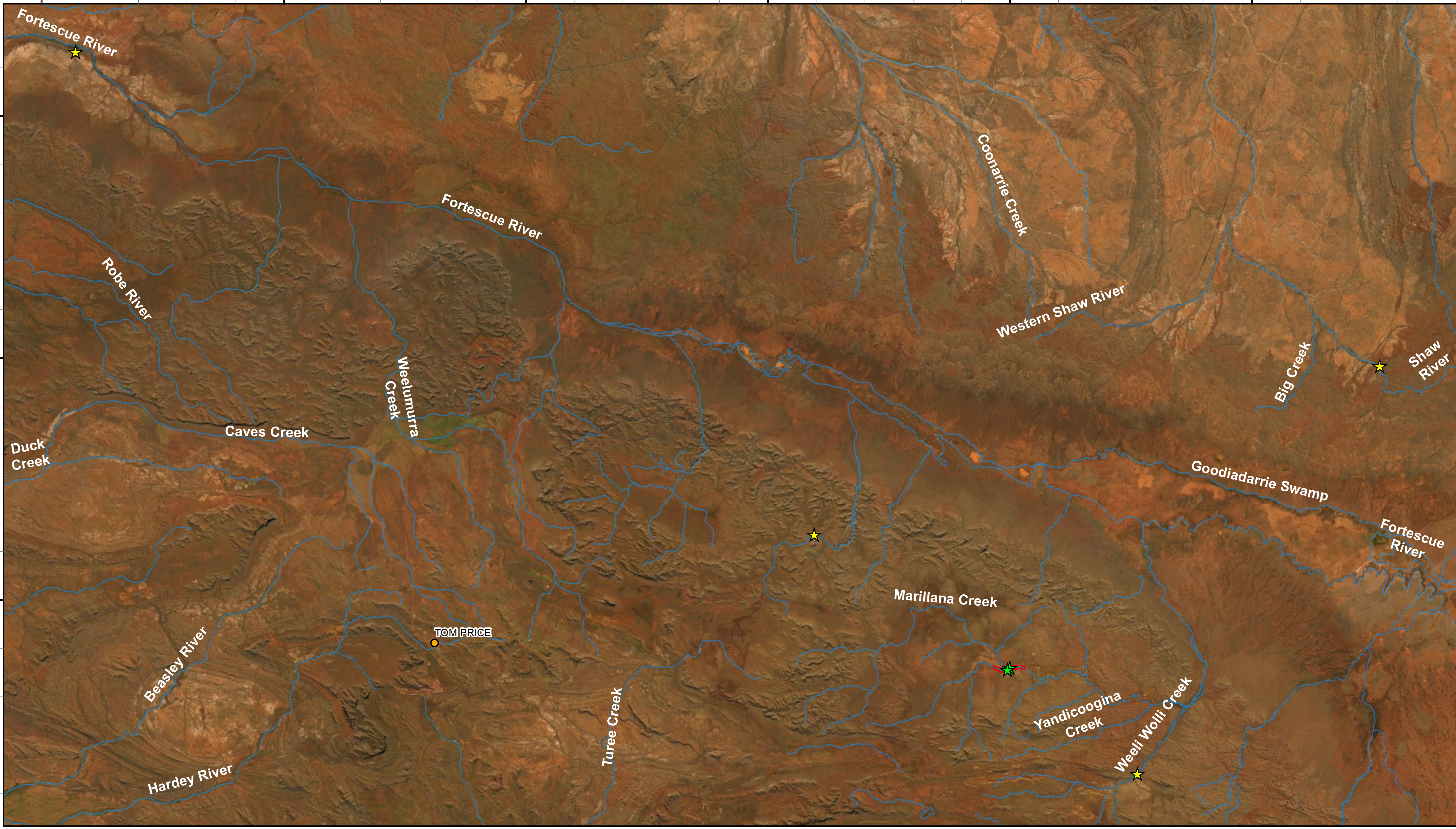
The water mite *Aspidiobates pilbara* is a Pilbara endemic known only from springs and permanent pools in good ecological condition. During the PBS, it was recorded from the Millstream Delta (type locality), Fortescue Falls, Bamboo Spring, and Weeli Wolli Spring. During the current study, *A. pilbara* was recorded from MarC2 and MarC3 in the dry 2020 (Figure 4.14).

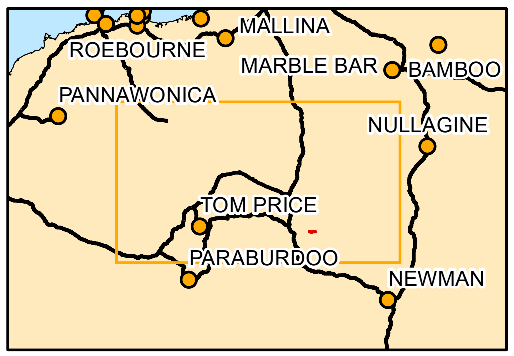
Coleoptera

The beetle *Haliplus fortescueensis* was first described from a specimen collected during the PBS from Fortescue Marsh West (Pinder *et al.*, 2010; Watts & McRae, 2010). It is a Pilbara endemic with a restricted and perhaps disjunct distribution. Its main area of occurrence is restricted to the Fortescue Marsh region, including the marsh and associated claypans, Coondiner Pool, and Marillana Creek (Watts & McRae 2010; Jess Delaney, unpub. data) (Figure 4.15). However, *H. fortescueensis* was also recorded once from a claypan near Port Hedland (Watts & McRae 2010). The origin of that particular record and whether it is a true representation of the species distribution is unknown. The main populations are all located in relatively close proximity, and within areas currently impacted or proposed for mining. In the current study, *H. fortescueensis* was recorded from MarC4 in the wet 2021.

4.8.3 Introduced macroinvertebrate taxa

Only one introduced macroinvertebrate taxon was recorded during the current study, from reference site WWS. The redclaw (*Cherax quadricarinatus*), a species of freshwater crayfish, was recorded in both seasons and is discussed further below (section 4.9).





Legend

Study Area

Major Creeks

Records of *Aspidiobates pilbara*

Current Survey

Previous Surveys

N

biologic Environmental Survey

Scale: 1:750,000

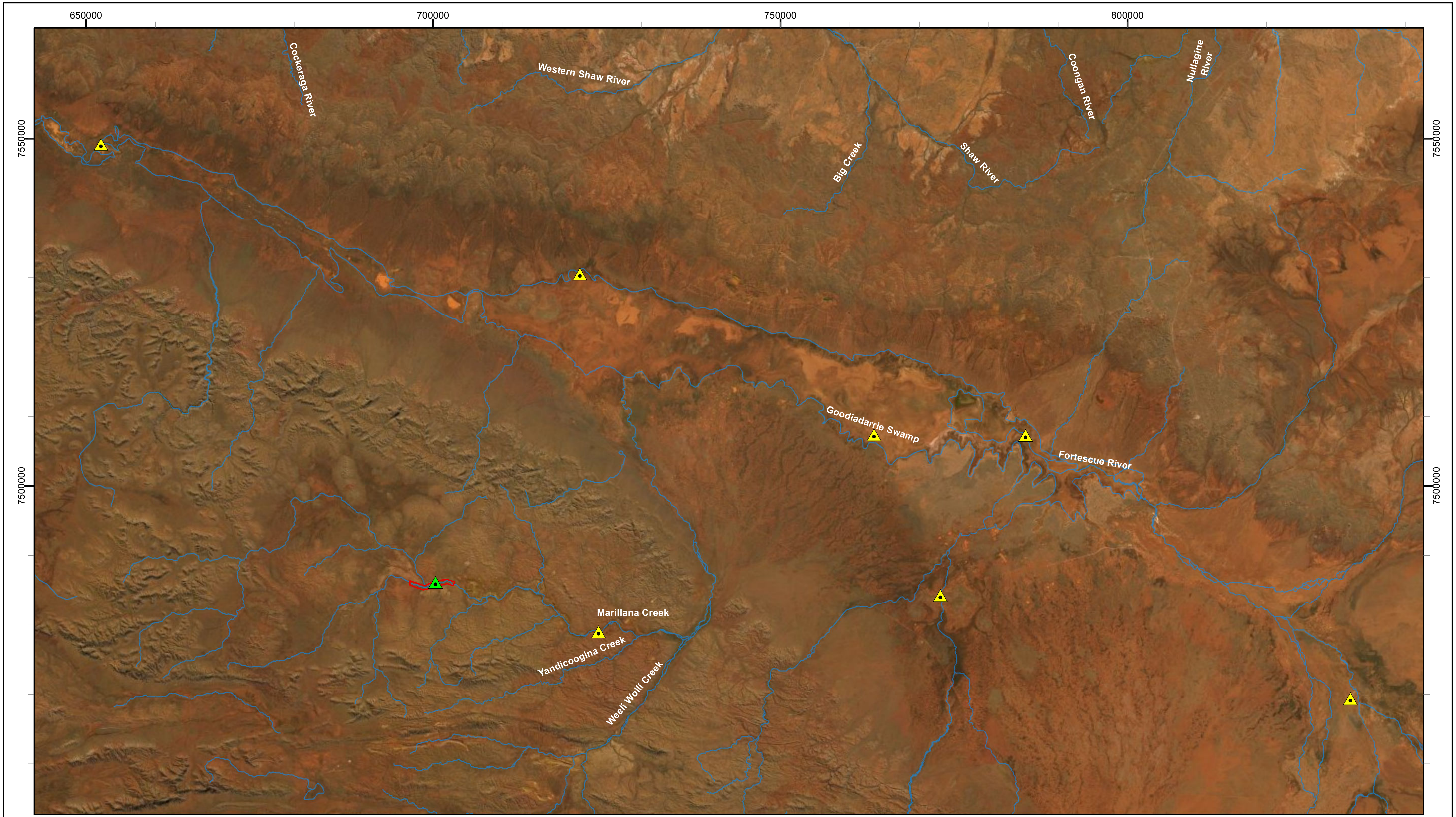
0 10 20 30 40 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 18/02/2022

BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.14: Location records for the conservation significant water mite *Aspidiobates pilbara*



Legend

Study Area

Major Creeks

Records of *Haliplus fortescueensis*

Current Survey

Previous Survey

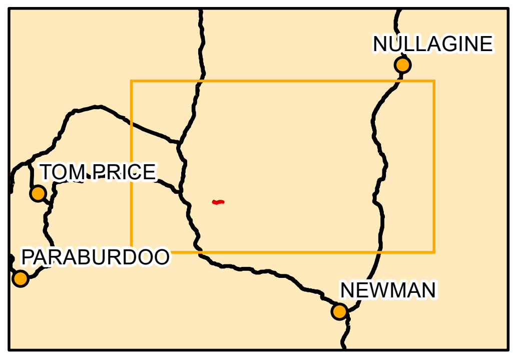
N

biologic Environmental Survey

Scale: 1:500,000

0 10 20 30 Km

Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994 Created 18/02/2022



BHP WAIO

MAC Phase 4: Marillana Creek Baseline Aquatic Ecosystem Survey

Figure 4.15: Location records for the conservation significant beetle *Haliplus fortescueensis*

4.8.4 Macroinvertebrate comparison with other studies

Macroinvertebrate richness was compared to the other aquatic studies undertaken in the area detailed in section 4.2 above (for those studies which sampled more than one replicate site within a creek system). As with the zooplankton data, Weeli Wolli Creek sites were split into Weeli Wolli Spring and Weeli Wolli Creek, and BENS and MACREF2 sites were removed due to a lack of replication. The macroinvertebrate dataset was amalgamated, and taxonomy aligned, prior to analysis to ensure any differences in taxonomic knowledge between samplers and years was accounted for.

The Study Area generally recorded similar average richness to reaches of Marillana Creek downstream and greater richness than nearby Yandicoogina Creek (Figure 4.16). Overall, differences in macroinvertebrate richness were significant between creek (Two-way ANOVA; df = 5, F = 4.43, p < 0.001), but not between season (df = 1, F = 0.003, p = 0.956). There was no significant interaction between creek and season (df = 5, F = 0.46, p = 0.802). The Tukey's post-hoc test indicated that Weeli Wolli Creek upstream sites had significantly lower average taxa richness and Weeli Wolli Spring and Davis River had significantly higher average taxa richness. Average macroinvertebrate richness recorded from the Study Area was statistically similar to all other creeklines/reaches included in the analysis, including the Weeli Wolli Spring PEC and the Davis River (Figure 4.16).

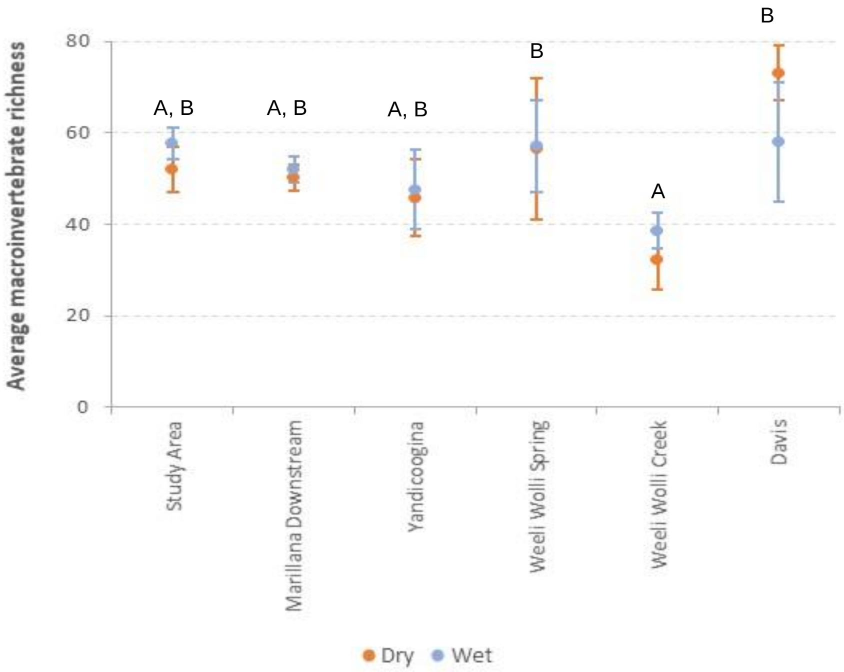


Figure 4.16: Average macroinvertebrate taxa richness (± se) recorded from Marillana Creek within the Study Area, in comparison to other studiesand nearby creeks.

For multivariate analyses, all data were included, i.e., MACREF2 and BENS were also incorporated into the dataset. Macroinvertebrate assemblages of Marillana Creek within the Study Area formed a relatively tight cluster, which was generally positioned close in ordination space to the remainder of Marillana Creek (i.e., Marillana-Downstream as sampled by WRM previously, and the Marillana reference site MACREF2, indicated as Marillana on the ordination) (Figure 4.17). Macroinvertebrate assemblages of the Study Area were also similar to BENS (indicated as WWS2 in the ordination), but generally separated from the main WWS and Davis River sites (Figure 4.17). Lower Marillana Creek and Weeli Wolli Creek (upstream of the spring) showed greater within-creek variability than Marillana Creek within the Study Area. Overall, there was a significant difference in macroinvertebrate assemblages between creek (Two-way ANOSIM; R = 0.48, *p* < 0.001), but the low R for season (R = 0.13) indicated that wet and dry assemblages were barely separable in ordination space (Figure 4.18: nMDS ordination of macroinvertebrate assemblages as above, but with samples identified by season.). Pairwise post-hoc results indicated that assemblages of Marillana Creek within the Study Area were most similar to the Marillana reference site (MACREF2) and BENS (WWS2; the second upstream occurrence of the Weeli Wolli Spring PEC) (Table 4.7).

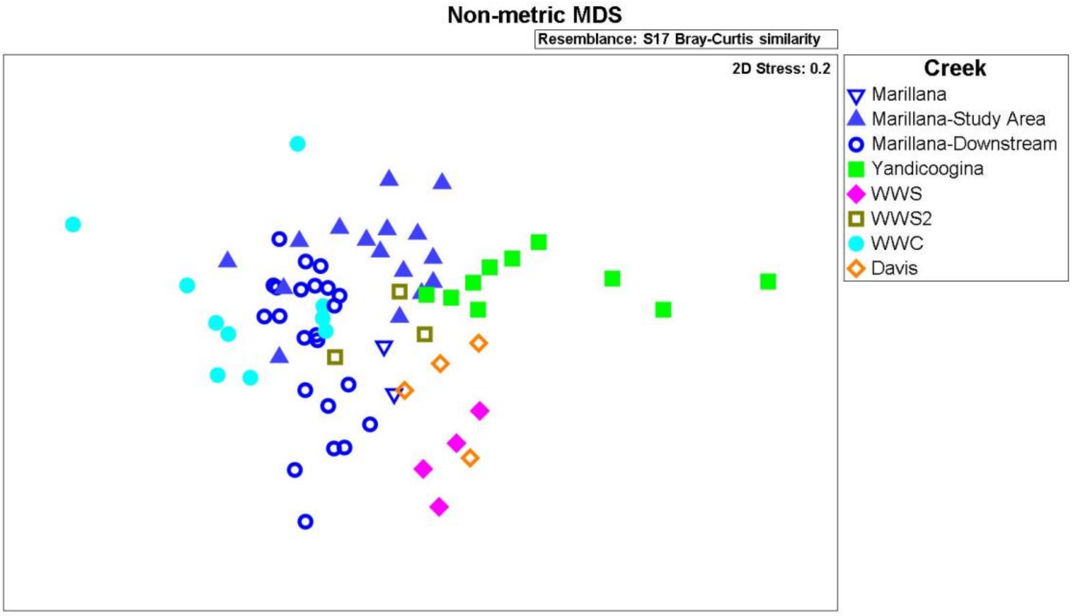


Figure 4.17: nMDS of macroinvertebrate assemblages recorded during the current study, as well as other studies and the previous PBS data. Samples are identified by creek.

Utilising data from the current study only, three environmental (water quality and habitat) variables were found to significantly influence the macroinvertebrate assemblages (BVSTEP; correlation = 0.58, p = 0.002). These were turbidity, maximum water depth and percentage habitat cover by root mats.

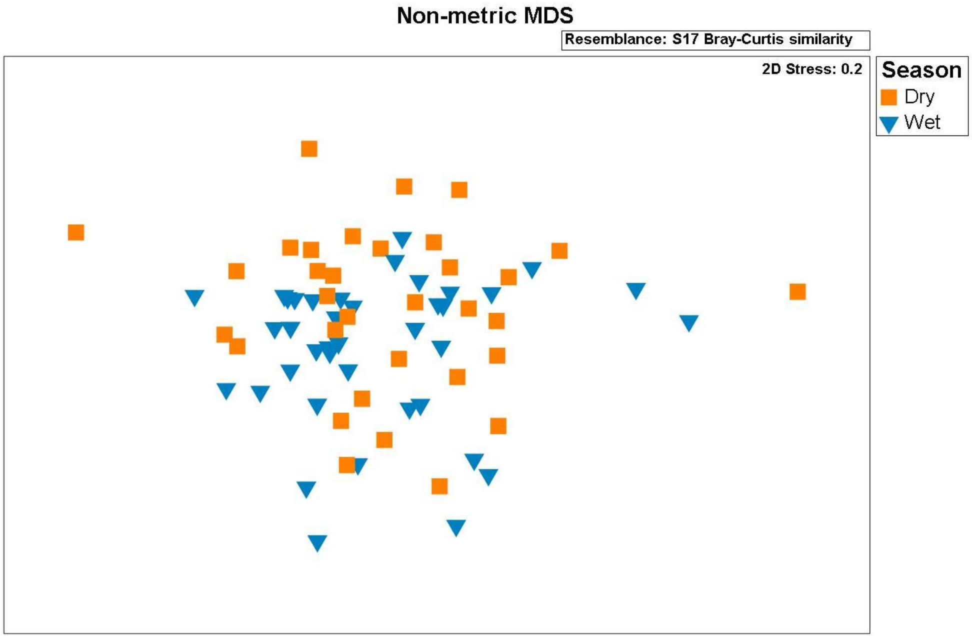


Figure 4.18: nMDS ordination of macroinvertebrate assemblages as above, but with samples identified by season.

Table 4.7: Post-hoc pairwise results comparing macroinvertebrate assemblages of Marillana within the Study Area to other creeks/reaches nearby. (NB: significant separations are indicated by red font).

Creek/reach	R	*p*-value
Marillana	0.32	0.123
Marillana-Down	0.34	<0.001
Yandicoogina	0.44	<0.001
WWS	0.84	<0.001
WWS2	0.12	0.252
WWC	0.46	0.003
Davis	0.54	0.006

4.9 Crayfish

A total of 16 individual invasive redclaw were removed from reference site WWS during the current study; with four individuals captured during the dry season (dip net), and 12 individuals removed during the wet (electrofishing). The sex ratio was 1:1, with no juveniles captured during the entire study (Table 4.8).

Table 4.8: Sex ratio for redclaw removed from WWS.

Sex	Dry 2020	Wet 2021	Total
Juvenile	0	0	0
Female	0	6	6
Male	0	6	6
Unknown	4	0	4
Total	**4**	**12**	**16**

As few individuals were recorded in the dry 2020, age-class structures were only examined for the wet 2021 specimens (Figure 4.19). Carapace length ranged from 39 to 63 mm in males and 40 to 60 mm in females. The highest abundance of individuals was within the 41 - 50 mm size class, which accounted for 31% of the total population removed (Figure 4.19). One berried female was removed. The redclaw population at WWS is abundant, healthy, and self-sustaining.

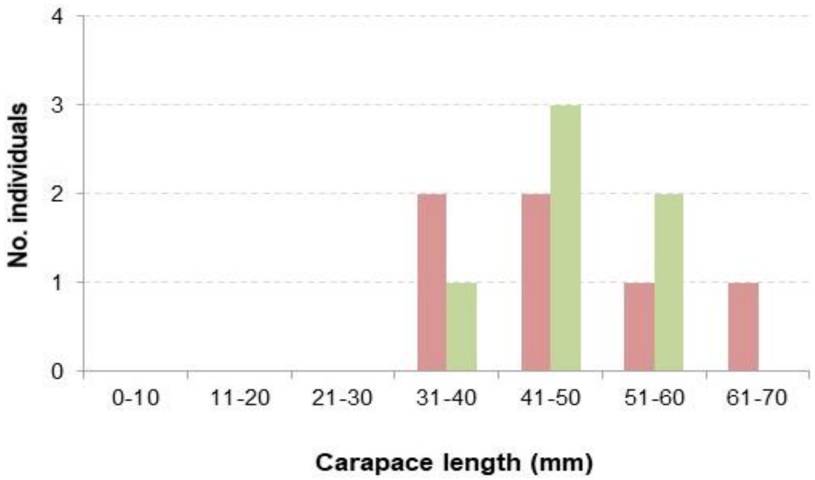


Figure 4.19: Size (mm CL) of redclaw removed from reference site WWS in wet 2021.

4.10 Fish

4.10.1 Species composition and richness

Four freshwater fish species from four families were recorded during the current study; the western rainbowfish *Melanotaenia australis* (Melanotaeniidae), Pilbara tandan *Neosilurus* sp.[8] (Plotosidae), spangled perch *Leiopotherapon unicolor* (Terapontidae), and Pilbara bony bream *Nematalosa* sp.[9] (Clupeidae) (Table 4.9). Of these, two were recorded from the Study Area (spangled perch and Pilbara tandan). One additional species, western rainbowfish, would be considered likely to populate the Study Area, as they are known from Marillana Creek downstream. It is not known why rainbowfish were not present in Marillana Creek during the current study, but future surveys will assist in assessing their presence in this part of the system. No introduced species were recorded or are currently known from the Study Area.

Results from this study are not unexpected given the fish fauna of the Pilbara is known to be characterised by low species diversity which is likely due to the region's aridity (Allen *et al.*, 2002; Masini, 1988; Morgan *et al.*, 2014). Greatest freshwater fish diversity in the region is

[8] The *Neosilurus* known from the Pilbara is genetically distinct to the described species *Neosilurus hyrtlii* (Unmack, 2013). The Pilbara species is currently known as *Neosilurus* sp. until further taxonomic work has been undertaken and descriptions made.
[9] The bony bream which occurs in the Pilbara is genetically distinct from the widespread *Nematalosa erebi* which occurs across northern Australia (Unmack, 2013). The Pilbara species is currently undescribed and as such is referred to as *Nematalosa* sp. here.

reported from relatively clear, permanent and semi-permanent pools, as was the case in the current study (i.e., from reference site SS).

4.10.2 Abundance

A total of 1,586 freshwater fish were recorded in the current study; 697 in the dry 2020 and 889 in the wet 2021 (Table 4.9). Fish were recorded from all sites sampled except MarC2 in the Wet 2021. Reference site SS recorded the greatest abundance (314 individuals in the wet), followed by Study Area site MarC6 (157 individuals in the dry (Table 4.9). Of the sites which recorded fish, the lowest abundance was recorded from MACREF1 in the dry 2020 (only two spangled perch observed). Diversity was greatest at SS in the wet 2021, with four species recorded.

Spangled perch was the most widespread and abundant species recorded within the Study Area, and in fact across the entire study. A total of 464 individual spangled perch were recorded in the dry and 454 individuals in the wet (across all sites). Western rainbowfish were the next most common species, with a total of 215 individuals in the dry 2020 and 288 in the wet 2021 (Table 4.9). Pilbara bony bream were the least abundant and widespread species across the entire study, In the Study Area, Pilbara tandan was the least abundant and widespread species. Across the entire study, Pilbara bony bream was recorded in the lowest abundance and occurrence (Table 4.9). Pilbara tandan was recorded from MarC1 and MarC5 in the Study Area and WWS, BENS and SS reference sites. Although Pilbara tandan tend to be recorded in low abundances due to their elusive and cryptic nature, they were observed in notably high abundance at WWS in the wet 2021 (79 individuals), where they were congregated in a pool below a flowing riffle/run. Pilbara tandan were also recorded in relatively high numbers from SS in the wet 2021 (34 individuals), but sampling at that site was facilitated by the use of an electrofisher which was utilised as part of sampling for a different BHP project.

4.10.3 Conservation significant fish species

Despite the low diversity known from the Pilbara, the region does support high endemicity in freshwater fishes (56%; Morgan *et al.* 2014). Two species recorded during the current study are endemic to the region; the Pilbara tandan (recorded from the Study Area) and the Pilbara bony bream. Both are representatives of genera which are wide-ranging across northern Australia; however, the species' recorded from the Pilbara are genetically distinct to common and widespread congeners (i.e., *Neosilurus hyrtlii* or *Nematalosa erebi*; Unmack 2013). Both species occur widely throughout the Pilbara and neither are currently listed as being of conservation significance. The Pilbara tandan may be less commonly recorded, as it has a cryptic nature, and is commonly found under snags and undercuts making it difficult to sample.

Table 4.9: Abundance of each freshwater fish species recorded from each site.

NB: D refers to dry season records, and W refers to wet season records.

		L. unicolor Spangled perch		*M. australis* Western rainbowfish		*Neosilurus* sp. Pilbara tandan		*Nematalosa* sp. Pilbara bony bream		Abundance		Diversity	
Creek	**Site**	**D**	**W**	**D**	**W**	**D**	**W**	**D**	**W**	**D**	**W**	**D**	**W**
Marillana Creek	**MarC1**	12	13	0	0	1	0	0	0	**13**	**13**	**2**	**1**
	MarC2	29	0	0	0	0	0	0	0	**29**	**0**	**1**	**0**
	MarC3	15	47	0	0	0	0	0	0	**15**	**47**	**1**	**1**
	MarC4	31	21	0	0	0	0	0	0	**31**	**21**	**1**	**1**
	MarC5	53	44	0	0	1	0	0	0	**54**	**44**	**2**	**1**
	MarC6	157	27	0	0	0	0	0	0	**157**	**27**	**1**	**1**
	MACREF2	29	25	0	0	0	0	0	0	**29**	**25**	**1**	**1**
Yandicoogina Creek	**MACREF1**	2	0	0	12	0	0	0	0	**2**	**12**	**1**	**1**
Weeli Wolli Creek	**WWS**	2	5	137	69	3	79	0	0	**142**	**153**	**3**	**3**
	BENS	22	73	42	62	9	4	0	0	**73**	**139**	**3**	**3**
Davis River	**SS**	63	166	22	89	0	34	1	25	**86**	**314**	**3**	**4**
	RW	49	33	14	56	0	0	3	5	**66**	**94**	**3**	**3**
Total abundance		**464**	**454**	**215**	**288**	**14**	**117**	**4**	**30**	**697**	**889**	**3**	**4**
										1,586			

4.10.4 Length-frequency analysis

The seasonal, yet unpredictable nature of rainfall and streamflow in the Pilbara is reflected in the opportunistic and periodic reproductive strategies of Pilbara freshwater fish (Beesley, 2006). Most species breed during the wet season, a time when new recruits and juveniles have the greatest chance of survival owing to the greater persistence of water/habitat, increased ecosystem productivity, and availability of food resources. Larvae have only a short window, usually in the order of a few days, with which to locate food or risk starving.

Analysis of population structure and age-classes present provides a way of characterising recruitment, the health of local fish assemblages, and therefore the environmental conditions present which may support or impede recruitment. Length-frequency analysis was undertaken for all fish species which were recorded in sufficient abundance. As Pilbara bony bream and western rainbowfish were only recorded from reference sites, these species were excluded from further analysis.

Spangled perch

Spangled perch breed during the wet season, between late November and March (Beesley, 2006), with spawning generally coinciding with flooding events (Morgan *et al.*, 2002). Several spawning events will occur over the wet season (Beesley, 2006). Maturity is attained after the first year, at around 58 mm TL for males and 78 mm TL for females. To allow for field determination of age-class (without knowing sex), size at maturity was considered to be 70 mm SL for the purposes of this study. Maximum size is ~ 300 mm TL

In both seasons, juveniles constituted the greatest proportion of spangled perch recorded in the Study Area (59% in the dry and 41% in the wet; Figure 4.20). Interestingly, a greater proportion of new recruits were recorded from the Study Area in the dry season (24%), in comparison to the wet (16%). This may be related to difficulties sampling the deeper waters during the wet season. Few spangled perch adults were recorded from the Study Area compared to reference sites (Figure 4.20). The presence of relatively high abundances of new recruits and juveniles suggest good levels of spangled perch breeding and recruitment within the Study Area.

Pilbara tandan

As it is a relatively new, undescribed species, the breeding ecology of the Pilbara tandan is unknown; however, information relating to congeneric species may provide some insight. In northern populations of the closely related *Neosilurus hyrtlii,* breeding occurs early in the wet season in shallow, sandy/gravelly areas of the upper reaches of creeks (Allen *et al.*, 2002) and fecundity ranges from 1,600 to 15,300 eggs (Orr & Milward, 1984). While other eel-tailed catfish, such as *Tandanus tandanus*, construct a unique nest into which eggs are spawned (Burndred *et al.*, 2017), the available evidence suggests that *N. hyrtlii* simply scatter fertilised eggs over the substrate (Orr & Milward, 1984). Sexual maturity in *N.hyrtlii* is attained at around 90 mm SL and they reach a maximum size of 400 mm TL (Bishop *et al.*, 2001).

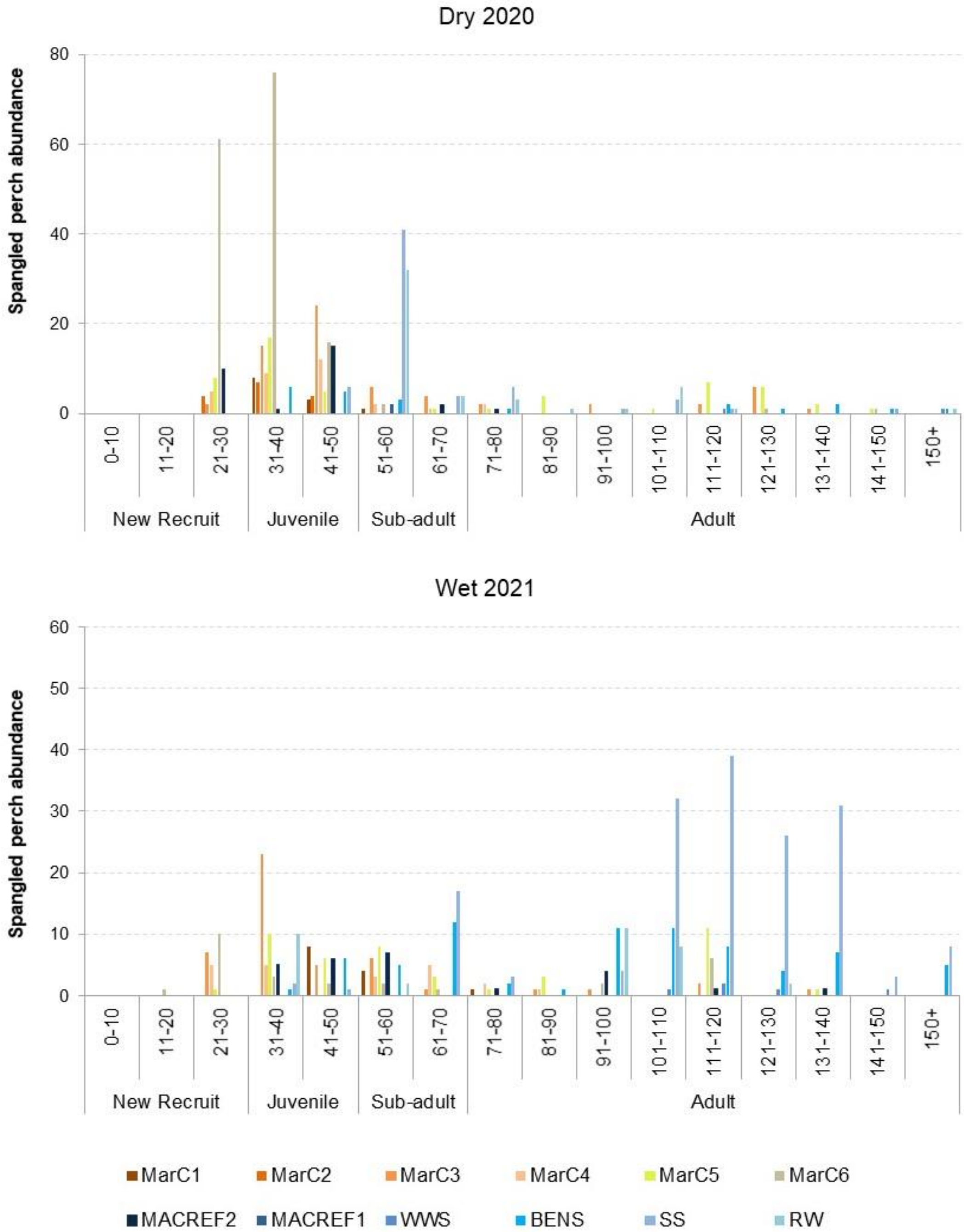


Figure 4.20: Length frequency analysis for spangled perch, in the dry (top) and wet (bottom).

Only two Pilbara tandan were recorded from the Study Area, one of which was a juvenile and the other an adult. Of the Pilbara tandan recorded from reference sites, most were juveniles in the dry 2020 and adults in the wet 2021. No new recruits were recorded from any site, in either season (Figure 4.21).

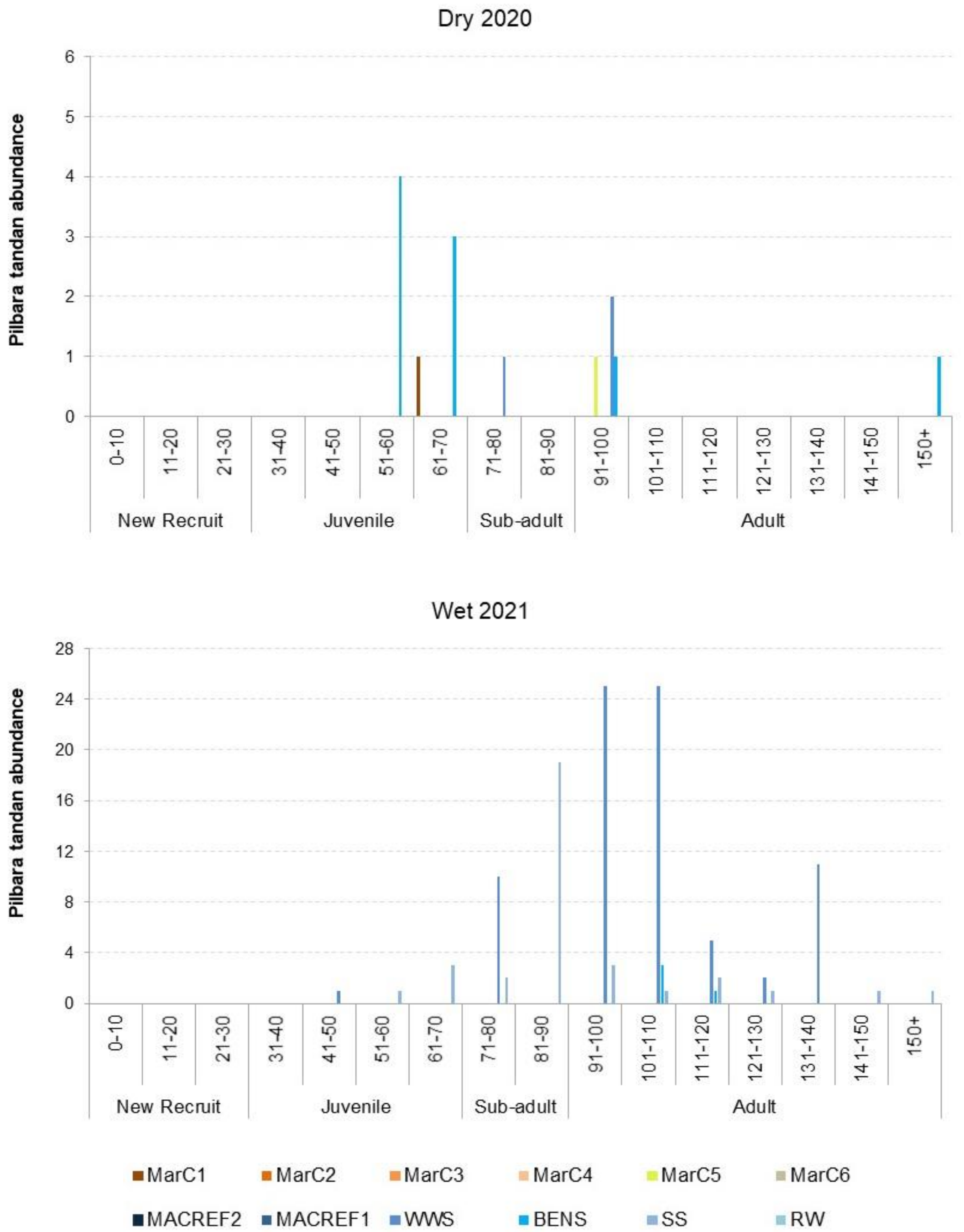


Figure 4.21: Length frequency analysis for Pilbara tandan, in the dry (above) and wet (below).

4.11 Other Vertebrate fauna

No other vertebrate fauna was recorded over the course of the study.

5 DISCUSSION

5.1 Habitat assessment

Numerous permanent and semi-permanent pools occur along the length of the Study Area, with some riffle/run sequences present in the upper extent of the Marillana Creek, i.e., from the reference site MACREF2 through to MarC2. Within the pools sampled, in-stream habitat diversity was high and comprised a variety of complex, heterogenous structures with which to support aquatic fauna, including submerged and emergent macrophytes, LWD, root mats, detritus, and trailing vegetation

5.2 Water quality

Surface waters of the Study Area pools sampled were characterised by fresh to brackish, well buffered, clear waters, with good dissolved oxygen saturation, slightly basic to circum-neutral pH, low nitrogen nutrient concentrations but high total phosphorus, and generally low dissolved metal concentrations. EC of most sites within the Study Area, except MarC5 and MarC6 (in the wet), exceeded both the ANZG (2018) DGV and the 1,500 µS/cm point of ecological stress. Generally, sites with EC less than 1,500 µS/cm experience little ecological stress, but a considerable shift in aquatic fauna assemblages is known to occur above this threshold. Many Pilbara waters have wide ranging EC, with large temporal and seasonal variability due to waters receding in the drier months and evapoconcentration of ions. Both Study Area and reference sites recorded EC in excess of 1,500 µS/cm. The aquatic biota may have been affected by the higher salinities, although relatively high richness was still recorded. Interestingly, several sites recorded marginally higher EC values in the wet season (MarC1, MarC2, MarC4 and MarC5). This illustrates the permanence of the water in this area, with limited evapoconcentration occurring during the dry season. Similar seasonal variation was recorded from permanent and spring reference sites (i.e., MACREF2, MACREF1 and WWS).

DO concentrations within the Study Area were generally within ANZG (2018) DGVs in the dry season, but were low in the wet. No values were below the point of ecological stress (~30%). Although oxygen needs of aquatic biota differ between species and life history stage, Butler and Burrows (2007) reported acute toxicity between 25% and 30% for six tropical, northern Australian freshwater species. Two Study Area sites recorded super-saturated DO (MarC1 and MarC6). The high DO at these sites was likely due to shallow water and the high abundance of submerged macrophyte and algae present, and therefore high rates of photosynthesis during the day. MarC1 was also flowing which creates oxygen in the process. These sites would likely experience oxygen stress overnight. The high DO recorded during the day could result in gas bubble disease, which can lead to emboli in the blood, heart and gill filaments of fish (Wang *et al.*, 2018). Effects can vary from mild to fatal depending on the extent of supersaturation, water temperature, and species, life history stage, and general health of the fish (Beeman *et al.*, 2003). No reference sites recorded DO saturation in excess of the ANZG (2018) upper DGV.

Ionic composition suggested surface waters of most sites within the Study Area are likely influenced by some connection to groundwaters, with dominance by Na and HCO_3. In the wet, MarC1 was dominated by Ca and HCO_3. The dominance of Ca and HCO_3 in surface waters often indicates connection to groundwater, while Na and Cl dominance tends to indicate contribution by rainfall and evapoconcentration effects (Cronan, 2009). Ionic composition of MarC6 indicated that it is likely fed predominately by rainfall currently (Na and Cl dominance), and maintained by the clay and bedrock substrate which has low transmissivity.

Nitrogen nutrient concentrations within the Study Area were low and below toxicity DGVs and most eutrophication DGVs. The only exception was total N, which was marginally in excess of the eutrophication DGV at most Study Area sites, in at least one season. Comparably elevated concentrations were also recorded from reference sites. In contrast, total P concentrations were high, and in excess of the eutrophication DGV, across all Study Area and reference sites, in both seasons. Concentrations at MarC6 were notably high in the dry 2020, with total P being more than 16 times the DGV. The eutrophication DGV is designed to protect aquatic ecosystems from the effects of nuisance algal and macrophyte growth. Excessive plant growth can physically smother aquatic invertebrates, as well as deplete oxygen in the water, due to increased biological oxygen demand as plants decay and are decomposed by bacteria. The relationship between nitrate-enrichment and enhanced algal growth in freshwaters is well documented, often resulting in very high density/abundance but low species richness (Camargo & Alonso, 2006; Wagenhoff *et al.*, 2011). While the idea that phosphorus (as FRP or total P) is the primary limiting factor for algal growth in freshwaters has been challenged as too simplistic (Beck & Hall, 2018; Elser *et al.*, 2007; Muhid & Burford, 2012), any additional nutrient inputs to the Study Area (such as from cattle or inputs from groundwater discharge) would increase the risk of eutrophication.

While dissolved metal concentrations were generally low, dB exceeded the 99% toxicity DGV at all Study Area sites and the 95% toxicity DGV at MarC2, MarC3 and MarC4. The seemingly high dB concentrations recorded in the current study are not atypical for Pilbara surface waters, with many pools and springs commonly recording values within the range seen here. Additionally, dCu was in excess of the 95% toxicity DGV at MarC6, and dFe was greater than the interim indicative working level at MarC2. The ANZECC DGVs are perhaps too conservative for freshwater ecosystems of the region.

5.3 Wetland flora

Groundwater Dependent Ecosystems (GDEs) and their associated vegetation is dependent on the presence of groundwater to meet some, or all, of their water requirements, either through surface expression or subsurface presence of groundwater (Hatton & Evans, 1998). The presence of specific phreatophytic (groundwater dependent) flora taxa indicates dependence of such vegetation on subsurface groundwater, which in turn indicates water permanence and potential significance of the system, especially for those not associated with large river or drainage systems (Rio Tinto, 2018). A 2.7 km portion of the Study Area from the confluence with the tributary down to MarC4 comprised what would be considered a significant GDE. This GDE extends a further 1.2 km on Marillana Creek upstream of the confluence with the tributary and includes the MACREF2 reference site. This reach of creekline contained groundwater dependent vegetation, including *Melaleuca argentea* which is a known obligate phreatophyte and is almost entirely dependent on groundwater (Graham *et al.*, 2003; McLean, 2014). It is considered a very high-level key mesophytic/hydrophytic indicator species[10]. In addition to *M. argentea*, other high level mesophytic/hydrophytic indicator species such as *Acacia ampliceps* and *Melaleuca bracteata* were recorded from this area, as well as the moderate-level indicator species *Cyperus vaginatus*, *Eleocharis geniculata* and *Schenoplectus subulatus* (Rio Tinto, 2021). In places, this groundwater dependent vegetation was dense. Downstream of this reach, a lower significance GDE was present for approximately 1.45 km, which included sparser sections of *Melaleuca argentea* and other mesophytic species (*Cyperus vaginatus* and *Schoenoplectus subulatus*). At MarC5, near the lower extent of the GDE, large, mature *M argentea* were present. The creekline and vegetation downstream of MarC5 may be impacted by drawdown from nearby mining. Upstream, on the tributary of Marillana Creek, a small, isolated GDE was present at MarC1 which extended for approximately 250 m. At this location, mesophytic /hydrophytic indicator species were recorded, including *Melaleuca argentea* and *Cyperus vaginatus*.

Wetland flora (emergent and submerged macrophytes) richness within the Study Area was compared against the PBS dataset, after taxonomy had been aligned. Richness from the Study Area was found to be high in comparison to nearby PBS sites, particularly at MarC4 and MarC6. These two sites recorded greater wetland flora richness than the Weeli Wolli Spring PEC, as sampled during the PBS, prior to any mining or invasive species impact. The high wetland flora richness from the Study Area is notable for the region, given the listing of the Weeli Wolli Spring Priority 1 PEC states: “Weeli Wolli Spring's riparian woodland and forest associations are unusual as a consequence of the composition of the understorey. The sedge and herbfield communities that fringe many of the pools and associated water bodies along the main channels of Weeli Wolli Creek have not been recorded from any other wetland site in the Pilbara” (DBCA, 2017).

5.4 Zooplankton

A total of 77 zooplankton taxa was recorded from Marillana Creek within the Study Area, including protists, rotifers, copepods, ostracods and Cladocera. No taxa recorded from the Study Area are currently listed or of conservation significance. However, four ostracod taxa identified through a combined morphological and molecular approach appear to be restricted to the Study Area, or are currently known from few records. Such taxa include:

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[10] Key mesophytic/ hydrophytic indicator species for the differing levels of persistence and GDE signficance were based on Jeremy Naaykens’ proposed riparian ecohydrological assessment framework (Rio Tinto, 2021).

- *Bennelongia* `sp. Biologic-OSTR026` - recorded from MarC1 and currently known only from this location
- Cyprididae `sp. Biologic-OSTR014` - recorded from MarC3, MarC4 and MarC6. Previously recorded by Biologic from the Angelo River Project Area, located approximately 70 km to the south of the Study Area.
- Cyprididae `sp. Biologic-OSTR015` - recorded from MarC1. Previously known from the Angelo River Project Area (recorded from rehydrate samples and the hyporheos).
- Cyprididae `sp. Biologic-OSTR019` - recorded from MarC5 and MarC6. Also previously recorded from rehydrates collected from the Angelo River Project Area.

In general, richness recorded from the Study Area was comparable to, if not slightly higher than, reference sites. Seasonal variation within reference sites was high, with lower zooplankton richness recorded from sites showing recent signs of flooding (i.e., WWS, RW, and SS). Being planktonic, zooplankton are highly responsive to increases in flow and flooding events, with high flows likely flushing zooplankton taxa from these reference sites, with the population yet to fully re-establish by the time of survey. Of the Study Area sites, only MarC6 showed any notable seasonal variation in zooplankton richness. At this site, considerably greater richness was recorded in the wet 2021, when the pool was considerably larger, and more habitat was available. The higher richness following the wet season flooding also indicates emergences and colonisation following inundation.

Zooplankton richness recorded during the current study was compared to previous surveys undertaken in nearby creek systems. The Study Area generally recorded average zooplankton richness similar to nearby creek systems, and statistical results indicated that overall, there was no significant difference between creeks or seasons. This was likely due to the high variability in zooplankton richness, within a creek system, within a season, as evidenced by the large standard error bars. Zooplankton are known to be patchily distributed, with notably high spatial and temporal variability (Klais *et al.*, 2016; Zhang *et al.*, 2019). Interestingly, variability within the Study Area was noticeably lower than all other creeks systems except Yandicoogina Creek, both within seasons and between seasons.

5.5 Hyporheos fauna

A total of 106 invertebrate taxa was recorded from hyporheic zones of Marillana Creek within the Study Area. Of these, a total of 11% are directly dependant on groundwater for persistence (8% stygobites and 3% permanent hyporheos stygophiles). The percentage of stygobitic taxa was greater than that reported previously for Pilbara hyporheic zones (i.e., 5% stygobitic fauna recorded in Halse *et al*. 2002), highlighting the strong groundwater connection within this reach of Marillana Creek.

Generally, richness of hyporheos fauna (stygobites, permanent hyporheos stygophiles, occasional hyporheos stygophiles, possible hyporheic taxa) within the Study Area was similar to reference sites. Greatest richness of groundwater dependent taxa (stygobites and permanent hyporheos stygophiles only) across all sites (including reference sites) was recorded from MarC2 in the dry 2020, and reference site SS in the wet 2021, closely followed by MarC4. This suggests a strong connection to groundwaters at these sites. In comparison, the lack of groundwater dependent taxa at MarC6, coupled with the issues accessing the hyporheic zone during sampling, indicates a relatively poor connection to groundwater at this site, which is likely due to groundwater drawdown from nearby mining.

One Potential SRE ostracod species was recorded from the Study Area hyporheos; *Gomphodella alexanderi*. This species is currently known only from Marillana Creek, lower Weeli Wolli Creek and Yandicoogina Creek, all in close proximity.

Two harpacticoid copepods, *Elaphoidella* sp. and *Parastenocaris* sp. may also represent species with restricted distributions. Several morphotypes of both *Elaphoidella* sp. and *Parastenocaris* sp. appear to be present across the Pilbara region, but due to taxonomic limitations it is unclear whether the specimens collected represent fauna that are new to science or range extensions of known fauna. The *Elaphoidella* sp. from the current study appears to be morphologically distinct from the known *Elaphoidella humphreysi* and may represent a species new to science or one of the other Pilbara morphotypes. It is unclear if the *Parastenocaris* sp. represents additional records of *Parastenocaris jane* which is known from Marillana Creek, or if it is a species new to science. *Parastenocaris jane*, while uncommon, has a widespread, if disjunct distribution across the Pilbara. Both genera appear to support several undescribed species across the Pilbara.

Several stygal water mites were also recorded within the Study Area that were potentially of significance (*Wandesia* sp., *Rutacarus* sp. and *Guineaxonopsis* sp.). These specimens could not be identified further due to lack of taxonomic information. However, all three genera are relatively uncommon and include undescribed species from across the Pilbara.

5.6 Macroinvertebrates

A total of 199 macroinvertebrate taxa was recorded from the Study Area, comprising Hydrozoa, Platyhelminthes, Nematomorpha, Gastropoda, Hirudinea, Ooligochaeta, Polychaeta, Acarina, Coleoptera, Diptera, Ephemeroptera, Hemiptera, Lepidoptera, Odonata and Trichoptera). Within-site macroinvertebrate diversity was high (≤ 44 taxa in the Study Area), with greatest richness from the Study Area being recorded from MarC2 (78 taxa in the wet) and MarC5 (76 taxa in the dry). The tributary site, MarC1, recorded the lowest richness (44 taxa in the dry and 46 in the wet).

The composition of macroinvertebrates was generally similar to most Pilbara pools, being dominated by slow flow and relatively tolerant taxa (Pinder *et al.,* 2010). Taxa which require faster flows, such as Lepidoptera and *Cheumatopysche* caddisflies (Trichoptera) were generally restricted to the flowing reference sites. Of note within the Study Area, however, was the high richness of odonates, particularly at MarC5 (14 taxa in the dry) and MarC6 (11 taxa in the wet). The diversity and composition of odonate assemblages is known to be related to the abundance and richness of littoral zone wetland flora, extent of riparian disturbance, benthic substrate granularity and in-stream productivity (Butler & deMaynadier, 2007). Although habitat preferences may vary depending on species, most damselflies and hawker dragonflies require substantial submerged and emergent macrophytes with which to lay their eggs and ensure protection from predators (Paulson, 2019). Females have a sharp ovipositor which they use to cut into vegetation and deposit their eggs. Other species use waterside vegetation as perches (Theischinger *et al.*, 2021). The high diversity of odonate larvae at MarC5 and MarC6 suggests healthy, reasonably extensive riparian vegetation and a high abundance and diversity of submerged and macrophytes.

Macroinvertebrate richness was compared statistically to previous aquatic surveys undertaken in the area. Overall, differences in macroinvertebrate richness were significant between creeks, but not between seasons. The Tukey's post-hoc test indicated that Weeli Wolli Creek upstream sites had significantly lowest average taxa richness and Weeli Wolli Spring and Davis River had significantly highest. Macroinvertebrate richness from the Study Area was statistically similar to all other creeklines/reaches included in the analysis, including the Weeli Wolli Spring PEC (as sampled during the PBS prior to any disturbance or mining impact), and the Davis River (also known for its high richness of aquatic fauna) (Kendrick & McKenzie, 2001).

Multivariate analyses on the same dataset of current and previous surveys indicated that macroinvertebrate assemblages of the Study Area were statistically similar to those from the Marillana Creek reference site (MACREF2) and BENS (the second occurrence of the Weeli Wolli Spring PEC). Study Area macroinvertebrate assemblages were significantly different to all other creeks/reaches included in the analysis (i.e., Marillana Creek downstream of the Study Area near Yandi, Yandicoogina Creek, Weeli Wolli Spring, Upper Weeli Wolli Creek and the Davis River).

While most aquatic macroinvertebrates recorded from the Study Area were common, ubiquitous species, several species were of conservation significance, including:

- The Pilbara pin damselfly *Eurysticta coolawanyah* (MarC5 and reference sites MACREF2, MACREF1, WWS, BENS and SS) - Vulnerable on the IUCN Redlist.
- The Pilbara emerald, *Hemicordulia koomina* (MarC1, MarC4, MarC5 and MarC6 and reference site BENS) - Vulnerable on the IUCN Redlist.
- The water mite *Aspidiobates pilbara* (MarC2 and MarC3 – Pilbara endemic known only from springs and permanent pools in good ecological condition.
- The beetle *Haliplus fortescueensis* (MarC4) – Pilbara endemic with its main area of occurrence restricted to the Fortescue Marsh region.

While no introduced macroinvertebrate taxa were recorded from the Study Area, the introduced redclaw, *Cherax quadricarinatus* (a species of freshwater crayfish) was recorded from reference site WWS in both seasons. The short term impacts of introduced crayfish have been widely reported in the literature and include habitat modification (Gherardi *et al.*, 2011), alteration to food webs, changes in nutrient and energy flow (Nyström *et al.*, 1999), introduction of disease, increased competition for limiting resources (Lynas *et al.*, 2006; Lynas *et al.*, 2007) and increased predation. Although there are no native crayfish species in the Pilbara, these impacts would still be considerable, especially on high conservation value aquatic ecosystems such as the Weeli Wolli Spring PEC. Some of the impacts to aquatic systems in the Pilbara have included changes to invertebrate assemblages and reduction in submerged macrophyte cover (Pinder *et al.*, 2019). Long term impacts of introduced crayfish include the possible decline of invertebrate taxa, amphibians and fish (Gherardi, 2007), and the potential to induce irreparable shifts in species diversity (Hobbs *et al.*, 1989). A specific study designed to assess the potential impact of redclaw on the WWS aquatic system is required. This should include an assessment of its diet (gut contents and stable isotope food web study) to determine prey items, to understand which species may be affected by predation and those which may be affected by competition for food resources. Micro-habitat use would also be interesting to examine, given redclaw are cryptic and tend to inhabit the same habitats as the Pilbara tandan.

5.7 Fish

Only two of the freshwater fish species likely to populate the Study Area were recorded; spangled perch *Leiopotherapon unicolor* (Terapontidae) and Pilbara tandan *Neosilurus* sp. (Plotosidae). Although considered likely to occur in the area, no western rainbowfish *Melanotaenia australis* (Melanotaeniidae) were recorded. Further sampling in the Study Area may locate this species, or confirm their absence. Although the Pilbara tandan is endemic to the Pilbara region, none of these freshwater fish species are of conservation significance and all are common and ubiquitous across the Pilbara. No introduced species were recorded. The abundance of new recruits and juvenile spangled perch suggested good levels of breeding and recruitment of this species within the Study Area

5.8 Other vertebrate fauna

While no other vertebrate fauna was recorded during the current study, several species likely occur within the Study Area, based on database search results and the authors experience in and around the Study Area. These include:

<u>Frogs</u>

- Desert tree frog (*Litoria rubella*)
- Pilbara toadlet (*Uperoleia saxatilis*)
- Mains frog (*Cyclorana maini*).

None of the aforementioned species are restricted or listed for conservation significance. All are relatively widespread along creeklines in the Pilbara region.

<u>Turtle</u>

- Flat-shelled, or dinner plate turtle (*Chelodina steindachneri*).

Chelodina steindachneri are known only from Western Australia, between the De Grey River in the north and the Irwin River in the south. They are found in both permanent and ephemeral systems and survive drought by aestivating in the riverbed or bank, and emerging in response to heavy rain (Cann, 1998). They have been recorded from systems that dry for more than two years. *Chelodina steindachneri* is not currently listed on any conservation lists.

Python

- Pilbara olive python (*Liasis olivaceus barroni*).

The Pilbara olive python is restricted to the Pilbara region and can be found in gorges, waterholes and on escarpments. It is currently listed as Vulnerable on both Federal (EPBC Act) and State (BC Act) conservation lists.

6 CONCLUSION

6.1 Main findings

The Study Area comprised GDEs of varying levels of significance based on the types and extent of GDVs present, including;

- Marillana Creek – High significance GDE from the confluence of the tributary and Marillana Creek (i.e., ~MarC2) extending 2.7 km downstream to MarC4.
- Marillana Creek - Lower significance GDE from MarC4 downstream 1.45 km to just below MarC5.
- Tributary – A small, isolated lower significance GDE extending for approximately 250 m and encompassing sampling site MarC1.

Several phreatophytes and mesophytic/hydrophytic indicator species were present in these areas. Of note, wetland flora richness within the Study Area was found to be high in comparison to nearby sites sampled as part of the PBS, including the Weeli Wolli Spring Priority 1 PEC, as sampled prior to any impacts from mining or invasive species (i.e., when flora richness was likely at its highest).

Several water quality characteristics indicated pools were maintained by both groundwater input and contribution by rainfall, with most sites being dominated by sodium (Na) cations and hydrogen carbonate (HCO_3) anions. MarC1was dominated by Na and chloride (Cl) in the dry 2020, and calcium (Ca) and HCO_3 in the wet, while MarC6 was dominated by Na and Cl in both seasons. Generally, there was a longitudinal decrease in Ca concentration along Marillana Creek, with concentrations decreasing along the Study Area reach. Additionally, there was no evidence of evapoconcentration over the dry season as pools receded, with EC generally being higher in the wet season, unlike most pools in the Pilbara. Ephemeral waters and creek pools generally display large seasonal variations in EC, with highest concentrations recorded in the dry season due to waters receding and the evapoconcentration of ions

Macroinvertebrate richness within the Study Area was high. In fact, macroinvertebrate richness was found to be statistically similar to sites known for their high diversity, including the Weeli Wolli Spring Priority 1 PEC (as sampled prior to any disturbance or mining impact) and the Davis River (Running Waters and Skull Springs).

Overall, three sites were found to hold considerable ecological value. These were:

1. **MarC2** which recorded a high diversity of GDV species, a relatively high richness of groundwater dependent invertebrate taxa (stygobites and permanent hyporheos stygophiles), conservation significant stygobitic species, taxa restricted to springs and permanent pools of high ecological condition, and overall high macroinvertebrate taxa richness.
2. **MarC4** which recorded a high diversity of GDV species, high richness of wetland flora (submerged and emergent macrophytes) in comparison to other creeks in the region,

a relatively high richness of groundwater dependent invertebrate taxa, restricted species and IUCN listed species.

3. **MarC5** which recorded high overall macroinvertebrate richness, high richness of odonate species, including IUCN listed species, and a high richness of Pilbara endemic taxa.

While most of the taxa recorded from the Study Area are generally common and ubiquitous across the Pilbara, a number are of conservation significance, and are either locally restricted or rarely collected (Table 6.1). Aside from notable invertebrate taxa recorded during the current study, several restricted species were considered likely to occur from the desktop assessment, database search and literature review (Table 6.2). Additional species of potential conservation significance which were considered to have a fairly high likelihood of occurrence within the Study Area, included the stygal ostracods *Meridiescandona facies*, *Meridiescandona marillanae*, *Neocandona* sp. 1, and *Notacandona boultoni*, the stygal isopod *Pygolabis weeliwolli*, Paramelitidae amphipods, the dragonfly *Ictinogomphus dobsoni* and the Pilbara olive python (Table 6.2).

Only two of the freshwater fish species likely to populate the Study Area were recorded; spangled perch *Leiopotherapon unicolor* (Terapontidae) and Pilbara tandan *Neosilurus* sp. (Plotosidae). Although considered likely to occur in the area, no western rainbowfish *Melanotaenia australis* (Melanotaeniidae) were recorded. Further sampling in the Study Area may locate this species, or confirm their absence. The abundance of new recruits and juvenile spangled perch suggested good levels of breeding and recruitment of this species within the Study Area.

6.2 Final remarks

This study represents the first aquatic ecosystem survey undertaken in this upper reach of Marillana Creek (aside from MarC6). Results from this survey provide an assessment of the ecological values and health of aquatic systems within the Study Area. Marillana Creek was found to support several GDEs of varying significance, with the main high significance GDE being located at the confluence with the tributary (~MarC2) and extending for 2.7 km downstream to MarC4. The Study Area was characterised by mature stands of the obligate phreatophyte *Melaleuca argentea* and facultative phreatophyte *Eucalyptus camaldulensis*. A diversity of other mesic species was also recorded in close association with the creek, such as *Cyperus vaginatus*, *Schoenoplectus subulatus* and *Typha domingensis*. The presence of phreatophytes, and more specifically, the obligate phreatophyte *Melaleuca argentea*,indicates that groundwater is persistently at or just below the surface. This is further supported by the presence of numerous permanent pools along the length of the Study Area. These pools provide important habitat for aquatic fauna and a resource for terrestrial invertebrate and vertebrate species. The current study found that six of these pools support; high richness of wetland flora taxa (submerged and emergent macrophytes), aquatic invertebrates with relatively restricted or disjunct distributions (i.e., *Haliplus fortescueensis*); species known to be restricted to springs and permanent pools of high ecological condition (i.e., *Aspidiobates pilbara*); conservation listed species (*Eurysticta coolawanyah* and *Hemicordulia koomina*); and two species of freshwater fish. Additionally, hyporheic zones within the Study Area supported potential SREs, including *Gomphodella alexanderi*, and Candonidae `sp. Biologic-OSTR009`. These important ecological values are supported by the high in-stream habitat diversity and heterogeneity characteristic of the system, as well as the strong connection to groundwater in this area.

Due to the aridity of the Pilbara, rivers of the region tend to be ephemeral. Streamflow is highly seasonal and variable, and generally occurs over the summer months in response to cyclonic events and thunderstorms. As such, permanent water sources in the region are relatively scarce and restricted to springs and permanent pools. Such predictable sources of water have high conservation importance as they support richer faunas than ephemeral water-bodies and provide a refuge for many species during drought (Halse *et al.*, 2002; Kay *et al.*, 1999). This is the case in the current study, with one permanent pool in the Study Area in particular found to support a notably high diversity of aquatic invertebrates, comparable to the Weeli Wolli Spring PEC and Skull Springs. Permanent pools are also known to provide an important source of animals for colonisation of newly flooded pools and maintenance of invertebrate species at the regional level (Halse *et al.*, 2002). Permanent springs in shaded gorges and river beds support a suite of mesic-adapted species that are otherwise rare in the region.

For riverine pools to be termed GDEs they must have demonstrated long-term connectivity to the groundwater and be maintained by groundwater discharge during drought periods. GDEs are those parts of the environment, the species composition, and natural ecological processes that are dependent on the permanent or temporary presence or influence of groundwater (Murray *et al.*, 2003). A number of physical and ecological elements highlight the close connection to groundwaters within the Study Area. These include:

- the presence of GDVs, including high-level mesophytic/hydrophytic indicators such as *Melaleuca argentea, Eucalyptus camaldulensis*, *Acacia ampliceps* and *Melaleuca bracteate* and moderate-level indicator species species *Cyperus vaginatus*, *Eleocharis geniculata* and *Schenoplectus subulatus*;
- the lack of any evapoconcentration or increased EC concentrations in the dry season;
- ionic composition dominated by carbonate anions, similar to other spring systems of the Pilbara; and
- the presence of stygofauna within the hyporheic zone.

As such, the stretch of Marillana Creek encompassing the Study Area is considered to hold high ecological importance on both a local and regional scale in the Pilbara region.

Table 6.1: Conservation significant taxa recorded from the Study Area.

Type	Species	Sites Recorded		Conservation significance
		Within Study Area	Reference Sites	
Ostracods	*Gomphodella alexanderi*	MarC2 (hyporheos)		SRE known only from the hyporheos of Marillana Creek, Yandicoogina Creek, lower Weeli Wolli Creek, and groundwater bores at Yandi.
	Bennelongia `sp. Biologic-OSTR026`	MarC1 (surface water)		Appears to be restricted to Marillana Creek based on current knowledge
	Cyprididae `sp. Biologic-OSTR014`	MarC3, MarC4 and MarC6 (all surface waters)		Currently known only from Marillana Creek and the Angelo River Project Area
	Cyprididae `sp. Biologic-OSTR015`	MarC1 (surface water)		Currently known only from Marillana Creek and the Angelo River Project Area (from surface waters and the hyporheos)
	Cyprididae `sp. Biologic-OSTR019`	MarC5 and MarC6 (surface waters)		Currently known only from Marillana Creek and the Angelo River Project Area (from surface waters)
Harpacticoids	*Elaphoidella* sp.	MarC4 (hyporheos)	SS (hyporheos)	Undescribed and may be new to science
	Parastenocaris sp.	MarC5 (hyporheos)	SS (hyporheos)	Represents either a specimen new to science or additional records for known fauna
Stygal mites	*Aspidiobates pilbara*	MarC2, MarC3 (surface waters)		Pilbara endemic known only from springs and permanent pools in good ecological condition
	Guineaxonopsis sp.	MarC1, MarC2, MarC4 (hyporheos)		Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara
	Rutacarus sp.	MarC4, MarC5 (hyporheos)	BENS (hyporheos)	Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara
	Wandesia sp.	MarC1, MarC5 (hyporheos)	MACREF2, WWS (hyporheos)	Species identification unknown, may be uncommon, with a disjunct or restricted distribution in the Pilbara
Damselfly	*Eurysticta coolawanyah*	MarC5 (surface waters)	MACREF2, MACREF1, WWS, BENS, SS (surface waters)	Vulnerable IUCN Redlist
Dragonfly	*Hemicordulia koomina*	MarC1, MarC4, MarC5, MarC6 (surface waters)	BENS (surface waters)	Vulnerable IUCN Redlist
Beetle	*Haliplus fortescueensis*	MarC4 (surface waters)		Pilbara endemic with a restricted distribution

Table 6.2 Conservation significant fauna considered likely to occur within the Study Area.

Type	Species	Distance of Study Area from nearest record	Potential habitat within Study Area	Recorded within Study Area	Likelihood of occurrence	Conservation significance
Stygal ostracods	*Meridiescandona facies*	~23 km	Yes	No	Likely	Known from Weeli Wolli and Yandicoogina Creeks
	Meridiescandona marillanae	~29 km	Yes	No	Likely	Known only from bores on Marillana Creek
	Neocandona sp. 1	~17 km	Yes	No	Likely	Known only from bores on Marillana Creek
	Notacandona boultoni	~22 km	Yes	No	Likely	Known from Weeli Wolli and Yandicoogina Creeks
Stygal isopods	*Pygolabis weeliwolli*	~20 km	Yes	No	Likely	SRE restricted to groundwater and hyporheos of Weeli Wolli and Marillana Creeks, and groundwater bores within Yandicoogina tenement
Stygal amphipods	Paramelitidae amphipods	~2 km	Yes	No	Almost Certain	Potential SRE
	Maarka weeliwolli	~27 km	Yes	No	Likely	Known only from Marillana and Weeli Wolli Creeks
Damselfly	*Agriocnemis kunjina*	~34 km	Yes	No	Unlikely	VU (IUCN)
	Austroagrion pindrina	~34 km	Yes	No	Unlikely	VU (IUCN)
Dragonfly	*Ictinogomphus dobsoni*	Within Study Area (Flat Rocks)	Yes	No	Almost Certain	NT (IUCN)
Pilbara olive python	*Liasis olivaceus barroni*	~27 km	Yes	No	Likely	VU (WA & EPBC)

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APPENDICES

Appendix A: Conservation Status Codes

International Union for Conservation of Nature

Category	Definition
Extinct (EX)	A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Extinct in the Wild (EW)	A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range. A taxon is presumed Extinct in the Wild when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form.
Critically Endangered (CR)	A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see Section V), and it is therefore considered to be facing an extremely high risk of extinction in the wild.
Endangered (EN)	A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see Section V), and it is therefore considered to be facing a very high risk of extinction in the wild.
Vulnerable (VU)	A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see Section V), and it is therefore considered to be facing a high risk of extinction in the wild.
Near Threatened (NT)	A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future
Data Deficient (DD)	A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases, great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.

Environment Protection and Biodiversity Conservation Act 1999

Category	Definition
Extinct (EX)	Taxa not definitely located in the wild during the past 50 years.
Extinct in the Wild (EW)	Taxa known to survive only in captivity.
Critically Endangered (CE)	Taxa facing an extremely high risk of extinction in the wild in the immediate future.
Endangered (EN)	Taxa facing a very high risk of extinction in the wild in the near future.
Vulnerable (VU)	Taxa facing a high risk of extinction in the wild in the medium-term future.
Migratory (MG)	Consists of species listed under the following International Conventions: Japan-Australia Migratory Bird Agreement (JAMBA) China-Australia Migratory Bird Agreement (CAMBA) Convention on the Conservation of Migratory Species of Wild animals (Bonn Convention)

Biodiversity Conservation Act 2016

Category	Definition
CR	Rare or likely to become extinct, as *critically endangered* fauna.
EN	Rare or likely to become extinct, as *endangered* fauna.
VU	Rare or likely to become extinct, as *vulnerable* fauna.
EX	Being fauna that is presumed to be extinct.
MI	Birds that are subject to international agreements relating to the protection of migratory birds.
CD	Special conservation need being species dependent on ongoing conservation intervention. (Conservation Dependant)
OS	In need of special protection, otherwise than for the reasons pertaining to Schedule 1 through to Schedule 6 Fauna. (Other specially protected species

Department of Biodiversity, Conservation and Attractions Priority codes

Category	Definition
Priority 1 (P1)	Taxa with few, poorly known populations on threatened lands.
Priority 2 (P2)	Taxa with few, poorly known populations on conservation lands; or taxa with several, poorly known populations not on conservation lands.
Priority 3 (P3)	Taxa with several, poorly known populations, some on conservation lands.
Priority 4 (P4)	Taxa in need of monitoring. Taxa which are considered to have been adequately surveyed, or for which sufficient knowledge is available, and which are considered not currently threatened or in need of special protection but could be if present circumstances change.

Appendix B: Default ANZECC/ARMCANZ (2000) water quality guidelines

Default trigger values for some physical and chemical stressors for tropical Australia for slightly disturbed ecosystems (TP = total phosphorus; FRP = filterable reactive phosphorus; TN = total nitrogen; NOx = total nitrates/nitrites; NH4+ = ammonium). Data derived from trigger values supplied by Australian states and territories, for the Northern Territory and regions north of Carnarvon in the west and Rockhampton in the east (ANZECC/ARMCANZ 2000).

Aquatic Ecosystem	Analyte						
	TP mg/L	FRP mg/L	TN mg/L	NOx mg/L	NH_4^+ mg/L	DO % saturation[f]	pH
Upland River[e]	0.01	0.005	0.15	0.03	0.006	90-120	6.0-7.5
Lowland River[e]	0.01	0.004	0.2-0.3[h]	0.01[b]	0.01	85-120	6.0-8.0
Lakes & Reservoirs	0.01	0.005	0.35[c]	0.01[b]	0.01	90-120	6.0-8.0
Wetlands[3]	0.01-	0.05-	0.35-1.2[g]	0.01	0.01	90[b]-120 [b]	6.0-8.0

b = Northern Territory values are 0.005mg/L for NO_x, and < 80 (lower limit) and >110% saturation (upper limit) for DO;

c = this value represents turbid lakes only. Clear lakes have much lower values;

e = no data available for tropical WA estuaries or rivers. A precautionary approach should be adopted when applying default trigger values to these systems;

f = dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability;

g = higher values are indicative of tropical WA river pools;

h = lower values from rivers draining rainforest catchments.

Default trigger values for salinity and turbidity for the protection of aquatic ecosystems, applicable to tropical systems in Australia (ANZECC/ARMCANZ 2000).

Salinity	(µs/cm)	Comments
Aquatic Ecosystem		
Upland & lowland rivers	20-250	Conductivity in upland streams will vary depending on catchment geology. The first flush may result in temporarily high values
Lakes, reservoirs & wetlands	90-900	Higher conductivities will occur during summer when water levels are
Turbidity	**(NTU)**	
Aquatic Ecosystem		
Upland & lowland rivers	2-15	Can depend on degree of catchment modification and seasonal
Lakes, reservoirs & wetlands	2-200	Most deep lakes have low turbidity. However, shallow lakes have higher turbidity naturally due to wind-induced re-suspension of sediments. Wetlands vary greatly in turbidity depending on the general condition of the catchment, recent flow events and the water

Guideline values for toxicants at alternative levels of protection (in mg/L). Values in grey shading are applicable to typical *slightly-moderately disturbed systems* (ANZECC/ARMCANZ 2000).

Chemical			**Guideline values for freshwater mg/L Level of protection (% species)**			
			99%	**95%**	**90%**	**80%**
Metals and metalloids						
Aluminium	pH > 6.5		0.027	0.055	0.08	0.15
Aluminium	pH < 6.5		ID	ID	ID	ID
Arsenic (As III)			0.001	0.024	0.094^C	0.36^C
Arsenic (AsV)			0.0008	0.013	0.042	0.14^C
Boron			0.09	0.37^C	0.68^C	1.3^C
Cadmium		H	0.00006	0.0002	0.0004	0.0008^C
Chromium (Cr III)		H	ID	ID	ID	ID
Chromium (Cr IV)			0.00001	0.001^C	0.006^A	0.04^A
Cobalt			ID	ID	ID	ID
Copper		H	0.001	0.0014	0.0018^C	0.0025^C
Iron		G	ID	ID	ID	ID
Lead		H	0.001	0.0034	0.0056	0.0094^C
Manganese			1.2	1.9^C	2.5^C	3.6^C
Mercury (inorganic)		B	0.00006	0.0006	0.0019^C	0.0054^A
Mercury (methyl)			ID	ID	ID	ID
Molybdenum			ID	ID	ID	ID
Nickel		H	0.008	0.011	0.013	0.017^C
Selenium (Total)		B	0.005	0.011	0.018	0.034
Selenium (SeIV)		B	ID	ID	ID	ID
Uranium			ID	ID	ID	ID
Vanadium			ID	ID	ID	ID
Zinc		H	0.0024	0.008^C	0.015^C	0.031^C
Non-metallic inorganics						
Ammonia		D	0.32	0.9^C	1.43^A	2.3^A
Chlorine		E	0.0004	0.003	0.006^A	0.013^A
Nitrate		J	1.0	2.4	3.4^C	17^A

Notes:

Most guideline values listed here for metals and metalloids are *High Reliability* figures, derived from field or chronic NOEC data (see 3.4.2.3). The exceptions are *Moderate Reliability* for freshwater aluminium (ph>6.5) and manganese.

Most non-metallic inorganics are *Moderate Reliability* figures, derived from acute LC50 data (see section 3.4.2.3). The exception is *High Reliability* for freshwater ammonia

A = Figure may not protect key test species from acute toxicity (and chronic) (Section 8.3.4.4)

B = Chemicals for which possible bioaccumulation and secondary poisoning effects should be considered (see Sections 8.3.3.4 and 8.3.5.7

C = Figure may not protect key test species from chronic toxicity (this refers to experimental chronic figures or geometric mean for species) - check Section 8.3.7 for spread of data and its significance.

D = Ammonia as TOTAL ammonia as [NH_3_N] at pH 8. For changes in trigger value with pH refer to Section 8.3.7.2

E = Chlorine as Total Chlorine, as [Cl]; see Section 8.3.7.2

F = Figures protect against toxicity and do not relate to eutrophication issues. Refer to Section 3.3 if eutrophication is a concern.

G = There were insufficient data to derive a reliable guideline value for iron. The current Canadian guideline level is 0.3 mg/L which could be used as an interim working level. However, further data are required to establish a figure appropriate for Australian and New Zealand waters.

H = Chemicals for which algorithms have been provided in table 3.4.3 to account for the effects of hardness. The values have been calculated using a hardness of 30 mg/L $CaCO_3$. These should be adjusted to the site-specific hardness (see Section 3.4.3).

J = Figures relate to toxicity (not eutrophication). The ANZECC/ARMCANZ (2000) DGVs for nitrate have been found to be erroneous (ANZG, 2018). In the absence of updated values, ANZG (2018) suggest reference is made to current New Zealand nitrate toxicity guidelines, specifically the 'Grading' GVs published in the '*Updating Nitrate Toxicity Effects on Freshwater Aquatic Species*' report (NIWA, 2013). These New Zealand Grading DGVs for N_NO_3 are provided above.

Appendix C: Habitat results

Percentage cover by each of the in-stream substrate types.

Dry 2020

Type	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Within Study Area	MarC1	3	0	4	36	47	0	6	4
	MarC2	0	0	3	43	47	0	7	0
	MarC3	72	0	3	7	10	0	8	0
	MarC4	5	0	2	23	49	11	10	0
	MarC5	1	0	4	34	46	5	10	0
	MarC6	25	7	5	9	10	0	5	39
Reference sites	MACREF2	45	2	6	10	20	0	7	10
	MACREF1	79	0	0	6	10	0	5	0
	WWS	3	2	10	22	38	23	2	0
	BENS	5	7	12	20	27	15	12	2
	SS	5	12	2	20	30	29	1	1
	RW	15	5	10	17	25	26	2	0

Wet 2021

Type	Site	Bedrock	Boulders	Cobbles	Pebbles	Gravel	Sand	Silt	Clay
Within Study Area	MarC1	3	0	4	36	50	5	0	2
	MarC2	0	0	0	10	40	50	0	0
	MarC3	90	0	0	2	3	5	0	0
	MarC4	25	5	10	10	20	25	0	5
	MarC5	0	0	2	5	10	83	0	0
	MarC6	0	10	0	20	10	30	0	30
Reference sites	MACREF2	95	0	0	0	0	5	0	0
	MACREF1	79	0	0	6	10	0	5	0
	WWS	3	2	10	22	38	23	2	0
	BENS	4	8	15	20	27	12	12	2
	SS	2	8	6	20	29	26	8	1
	RW	10	12	2	14	27	25	9	1

Percentage cover by each of the in-stream habitat types. NB: Inorganic sed. = inorganic sediment, Sub. Mac = submerged macrophyte, Emerg. Mac. = emergent macrophyte and Trailing Veg. = trailing vegetation.

Dry 2020

Type	Site	Inorganic seds	Sub.Mac.	Emerg.Mac.	Algae	LWD	Detritus	Roots	Trailing Veg.	Habitat Diversity
Within Study Area	MarC1	37	8	16	19	3	9	2	6	8
	MarC2	41	10	12	17	5	11	2	2	8
	MarC3	43	8	12	20	4	10	2	1	8
	MarC4	19	60	1	10	4	6	0	0	6
	MarC5	68	11	1	0	3	16	1	0	6
	MarC6	46	36	0	6	2	10	0	0	5
Reference sites	MACREF2	36	16	16	8	6	11	3	4	8
	MACREF1	22	8	21	25	6	11	3	5	8
	WWS	38	0	5	25	2	10	15	5	7
	BENS	35	5	7	10	12	20	8	3	8
	SS	27	35	2	5	7	20	3	1	8
	RW	52	7	0	2	10	20	8	1	7

Wet 2021

Type	Site	Inorganic seds	Sub.Mac.	Emerg.Mac.	Algae	LWD	Detritus	Roots	Trailing Veg.	Habitat Diversity
Within Study Area	MarC1	5	5	35	45	3	5	2	0	7
	MarC2	15	2	30	40	3	5	3	2	8
	MarC3	30	8	15	40	2	3	2	0	7
	MarC4	40	20	19	10	2	8	1	0	7
	MarC5	80	5	10	0	2	5	2	1	7
	MarC6	70	23	1	2	1	1	1	1	8
Reference sites	MACREF2	5	10	25	50	3	5	2	0	7
	MACREF1	22	8	21	25	6	11	3	5	8
	WWS	62	0	1	8	4	6	18	1	7
	BENS	44	0	3	8	12	22	8	3	7
	SS	42	12	8	2	5	18	12	1	8
	RW	25	25	2	18	7	15	5	3	8

Appendix D: Water quality results

Highlighted cells refer to values which are in excess of: > the 99% ANZECC DGV, and > the 95% DGV.

Dry 2020

		ANZG DGV		Within Study Area						Reference Sites					
	Units	99% GV	95% GV	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	SS	RW
Temperature	ºC			19.3	21.7	26.6	17.7	13.9	30.2	16.0	17.5	25.2	22.2	21.8	28.9
Conductivity (EC)	µS/cm		250	1590	2148	2379	2100	1150	1977	1485	748	938	953	702	1211
pH	pH units		6-8	7.83	7.37	8.37	8.11	8.36	9.24	8.08	7.55	7.65	8.00	7.80	7.27
Redox	mV			146.1	82.0	221.8	251.8	195.8	206.0	224.4	246.2	210.1	199.9	159.6	236.7
DO	%		85-120	147.9	89.6	106.3	90.8	57.6	182.9	84.7	73.7	77.5	47.7	45.1	81.3
Turbidity	NTU		15	11.9	4.1	2.6	3.6	3.4	12.2	2.9	3.8	0.2	3.6	1.0	0.1
TSS	mg/L			26	2	<2	3	8	38	3	2	<1	11	<1	<1
Alkalinity	mg/L			386	618	533	507	434	278	499	325	323	416	357	304
Hardness	mg/L			709	734	675	714	429	404	585	253	408	456	251	382
Na	mg/L			117	169	188	190	103	174	127	66	44	29	53	84
Ca	mg/L			109	93	46	55	43	25	81	33	71	65	44	64
Mg	mg/L			106	122	136	140	78	83	93	42	56	72	35	54
K	mg/L			13.9	20.9	23.4	21.7	15.6	18.6	17.9	5.6	9.6	6.8	5.2	10.9
HCO3	mg/L			386	618	496	507	427	190	499	325	318	416	357	304
Cl	mg/L			428	390	446	479	264	408	289	104	74	61	54	148
S_SO4	mg/L			143.0	146.0	139.0	165.0	52.6	108.0	100.0	1.9	58.0	35.4	20.1	82.7
CO_3	mg/L			<1	<1	36	<1	8	88	<1	<1	6	<1	<1	<1
dAl	mg/L	0.027	0.055	<0.005	<0.005	<0.005	<0.005	<0.005	0.010	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
dAs	mg/L	0.001	0.024	0.0007	0.0006	0.0007	0.0011	0.0005	0.0016	0.0004	<0.0002	0.0004	0.0004	0.0002	<0.0002
dB	mg/L	0.09	0.37	0.20	0.46	0.45	0.39	0.27	0.57	0.38	0.20	0.27	0.08	0.08	0.20
dBa	mg/L			0.195	0.172	0.066	0.074	0.085	0.044	0.134	0.035	0.010	0.057	0.357	0.017
dCd	mg/L	0.00006	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
dCo	mg/L			0.0005	0.0019	<0.0001	0.0002	0.0002	0.0004	<0.0001	<0.0001	<0.0001	0.0003	0.0001	<0.0001
dCr	mg/L	0.00001	0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0004
dCu	mg/L	0.001	0.0014	0.00018	0.00012	0.00013	0.00020	0.00047	0.00258	0.00009	0.00008	0.00016	0.00049	0.00015	0.00008
dFe	mg/L			0.182	0.357	0.051	0.178	0.054	0.020	0.034	0.040	<0.002	0.011	0.025	<0.002
dMn	mg/L	1.2	1.9	0.3390	0.6980	0.0120	0.0125	0.0539	0.0153	0.0148	0.0263	<0.0005	0.0772	0.2740	0.0007
dMo	mg/L			0.0002	0.0004	0.0002	0.0003	0.0003	0.0010	0.0002	0.0001	0.0002	0.0003	0.0004	0.0003
dNi	mg/L	0.008	0.011	<0.0005	0.0006	<0.0005	<0.0005	<0.0005	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
dPb	mg/L	0.001	0.0034	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
dS	mg/L			47.7	48.7	46.3	55.0	17.5	36.0	33.3	0.6	19.3	11.8	6.7	27.6
dSe	mg/L	0.005	0.011	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0005	0.0012	<0.0002	<0.0002	<0.0002	<0.0002	0.0018
dU	mg/L			0.0019	0.0036	0.0024	0.0027	0.0020	0.0013	0.0026	0.0002	0.0006	0.0006	0.0005	0.0016
dV	mg/L			0.0008	0.0019	0.0015	0.0058	0.0011	0.0057	0.0029	0.0004	0.0025	0.0014	0.0008	0.0017
dZn	mg/L	0.0024	0.008	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
N_NH_3	mg/L	0.32	0.90	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
N_NO_3	mg/L	1.00	2.40	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.29	<0.01	0.02	<0.01	0.02	1.73
N_NOx	mg/L		0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.29	<0.01	0.02	<0.01	0.02	1.73
TN	mg/L		0.30	0.50	0.09	0.31	0.28	0.35	2.02	0.35	0.09	0.02	0.17	0.08	1.63
TP	mg/L		0.01	0.046	0.039	0.030	0.030	0.032	0.161	0.032	0.047	0.018	0.020	0.019	0.012

Highlighted cells refer to values which are in excess of: > the 99% ANZECC D GV, and > the 95% DGV.

Wet 2021

		ANZG DGV		Within Study Area						Reference Sites					
	Units	99% GV	95% GV	MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	SS	RW
Temperature	°C			25.6	25.4	21.4	23.5	22.8	22.4	24.6	19.4	25.7	25.0	24.6	24.8
Conductivity (EC)	µS/cm		250	1614	2416	2185	2241	1227	868	1809	783	975	493	420	521
pH	pH units		6-8	7.47	7.57	8.03	8.04	8.04	8.91	8.16	7.89	7.42	7.22	7.81	7.89
Redox	mV			188.9	-40.4	195.9	236.7	230.3	203.3	209.7	222.9	124.7	183.7	146.8	22.0
DO	%		85-120	92.6	33.2	42.9	66.0	67.0	93.7	103.2	33.9	71.7	78.4	109.2	118.2
Turbidity	NTU		15	2.0	2.3	0.8	0.7	1.8	1.1	0.4	1.7	<0.1	0.7	0.7	6.3
TSS	mg/L			6	2	<1	1	3	2	1	1	<1	<1	<1	2
Alkalinity	mg/L			326	524	518	482	279	177	418	237	303	254	162	175
Hardness	mg/L			598	787	799	762	402	247	598	279	382	238	158	175
Na	mg/L			80	179	179	169	95	82	142	73	41	7	28	40
Ca	mg/L			111	104	104	91	51	23	82	38	68	46	33	34
Mg	mg/L			78	128	131	130	67	46	95	45	51	30	18	22
K	mg/L			13.7	24.8	24.1	23.4	15.3	12.6	21.5	7.5	8.9	3.1	4.3	5.8
HCO3	mg/L			326	524	518	482	279	152	404	237	303	254	162	166
Cl	mg/L			274	432	444	460	236	169	323	126	83	13	31	47
S_SO4	mg/L			89.2	140.0	137.0	125.0	65.4	52.8	108.0	29.5	58.9	8.3	13.8	24.6
CO_3	mg/L			<1	<1	<1	<1	<1	25	14	<1	<1	<1	<1	8
dAl	mg/L	0.027	0.055	<0.005	<0.005	<0.005	<0.005	<0.005	0.007	<0.005	<0.005	<0.005	<0.005	<0.005	0.012
dAs	mg/L	0.001	0.024	0.0003	0.0005	0.0006	0.0009	0.0004	0.0007	0.0003	0.0003	0.0003	0.0002	<0.0002	0.0003
dB	mg/L	0.09	0.37	0.25	0.61	0.57	0.53	0.36	0.36	0.58	0.27	0.21	0.03	0.07	0.11
dBa	mg/L			0.146	0.170	0.155	0.147	0.088	0.044	0.149	0.037	0.011	0.021	0.145	0.153
dCd	mg/L	0.00006	0.0002	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
dCo	mg/L			<0.0001	0.0003	0.0001	0.0002	<0.0001	0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
dCr	mg/L	0.00001	0.001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
dCu	mg/L	0.001	0.0014	0.00014	0.00032	0.00008	0.00040	0.00029	0.00096	0.00006	0.00020	0.00017	0.00055	0.00021	0.00055
dFe	mg/L			<0.002	0.317	0.017	0.020	0.052	0.010	0.023	0.213	<0.002	0.019	0.011	0.014
dMn	mg/L	1.2	1.9	0.0018	0.1060	0.0306	0.0252	0.0067	0.0011	0.0067	0.0550	<0.0005	0.0210	0.0559	0.0271
dMo	mg/L			0.0002	0.0004	0.0003	0.0003	0.0003	0.0004	0.0002	0.0005	0.0002	0.0002	0.0003	0.0005
dNi	mg/L	0.008	0.011	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
dPb	mg/L	0.001	0.0034	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
dS	mg/L			29.7	46.7	45.7	41.7	21.8	17.6	36.0	9.8	19.6	2.8	4.6	8.2
dSe	mg/L	0.005	0.011	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0003	0.0002	<0.0002	0.0002	<0.0002	0.0002	<0.0002
dU	mg/L			0.0011	0.0036	0.0034	0.0034	0.0015	0.0013	0.0016	0.0004	0.0008	0.0003	0.0004	0.0006
dV	mg/L			0.0030	0.0041	0.0011	0.0107	0.0025	0.0086	0.0015	0.0014	0.0018	0.0017	0.0021	0.0026
dZn	mg/L	0.0024	0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N_NH_3	mg/L	0.32	0.90	<0.01	<0.01	<0.01	0.05	0.05	0.02	0.02	0.02	<0.01	<0.01	<0.01	<0.01
N_NO_3	mg/L	1.00	2.40	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.13	0.21	0.04
N_NOx	mg/L		0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	0.13	0.21	0.04
TN	mg/L		0.30	0.07	0.07	0.14	0.08	0.24	0.34	0.07	0.16	0.03	0.12	0.46	0.11
TP	mg/L		0.01	0.030	0.035	0.029	0.026	0.025	0.020	0.040	0.038	0.014	0.011	0.023	0.018

Appendix E: Zooplankton taxonomic list

Values are log abundances (i.e., 1=1 individual, 2 = 2-10, 3 = 11-100, 4 = 101-1000, and so on).

Dry 2020

			Within Study Area						Reference					
Phylum/ Class/ Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
PROTISTA		Testate Amoeba	2	0	0	1	3	0	0	2	0	0	0	0
CILIOPHORA		Ciliate indet.	1	1	0	0	2	3	0	0	0	0	0	2
Prostomatea														
Prorodontida	**Colepidae**	*Coleps* sp.	0	0	0	2	2	0	0	0	0	0	0	0
Spirotrichea		cf. *Hypotrichia* sp.	0	0	0	3	0	0	2	0	0	2	2	0
ROTIFERA		Unidentified Rotifera	2	1	0	1	2	3	2	2	0	2	2	0
Bdelloidea		Bdelloidea spp. indet.	2	0	0	2	3	3	1	2	0	1	0	1
Monogononta														
Ploima	**Brachionidae**	*Brachionus angularis*	0	0	0	0	0	0	0	0	0	4	2	3
		Brachionus budapestinensis	0	1	0	0	0	0	0	0	0	0	0	0
		Keratella sp.	1	0	0	2	1	3	0	0	1	0	1	0
		Keratella procurva	0	0	0	0	0	0	0	0	0	4	0	0
		Keratella quadrata	0	0	0	0	3	3	2	0	0	0	0	0
		Keratella tropica	0	1	0	0	5	5	0	3	0	0	0	0
		Keratella valga	0	0	0	0	0	0	0	0	0	3	0	3
		Keratella cf. *slacki*	0	0	0	0	0	0	0	0	0	3	0	0
	Euchlanidae	*Euchlanis* sp.	0	0	0	0	0	0	0	0	0	2	1	0
	Habrotrochidae	Habrotrochidae spp.	0	2	0	2	0	0	0	2	0	1	0	0
	Lecanidae	*Lecane* sp.	0	2	2	1	0	0	1	0	1	0	0	0
		Lecane bulla	0	0	0	0	0	0	0	0	0	1	0	0
		Lecane cf. *decipiens*	3	0	0	0	0	0	0	1	0	0	0	0
		Lecane cf. *hamata*	2	0	0	0	0	0	0	0	0	0	0	0
		Lecane cf. *hornemanni*	0	0	0	2	0	0	0	0	0	0	0	0
		Lecane cf. *lunaris*	0	0	0	0	0	0	1	0	0	0	0	0
		Lecane cf. *opias*	3	0	2	2	0	0	0	1	0	0	0	0
		Lecane cf. *patella*	0	0	0	0	0	0	1	0	0	0	0	0
		Lecane cf. *pyrformis*	0	0	0	2	0	0	0	0	0	0	0	0
	Lepadellidae	*Colurella* cf. *uncinta*	3	2	3	2	2	0	0	2	0	0	0	0
		Colurella cf. *obtusa*	0	0	0	0	0	0	0	1	0	0	0	0
		Lepadella sp.	1	0	0	0	1	0	2	2	0	2	2	0
		Lepadella cf. *ovalis*	0	0	0	0	3	0	3	0	0	0	0	0
		Lepadella cf *vitrea*	0	0	0	0	0	0	0	0	0	3	0	0
		Squatinella sp.	1	0	0	0	0	0	0	0	0	0	0	0
	Mytilinidae	cf. *Lophocharis* sp.	0	0	0	0	0	0	0	1	0	0	0	0
	Proalidae	*Proales* sp.	2	0	0	0	0	0	0	2	0	0	0	0

Phylum/ Class/ Order	Family	Lowest taxon	Within Study Area MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	Reference MACREF2	MACREF1	WWS	BENS	SS	RW
	Synchaetidae	*Ploesoma* sp.	0	0	0	0	1	0	2	0	0	0	0	0
		Polyarthra cf. dolichoptera	0	0	0	0	0	0	0	0	0	0	2	0
	Testudinellidae	cf. *Pompholyx* sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Testudinella sp.	0	0	0	0	0	0	0	0	0	0	4	0
	Trichocercidae	*Trichocerca* sp.	1	0	0	2	0	5	0	0	1	0	0	0
		Trichocerca similis	0	0	0	0	0	0	0	0	0	4	2	0
		Trichocerca cf. *flagellata*	0	0	0	0	0	0	0	1	0	0	0	0
		Trichocerca cf. *bicristata*	2	2	1	0	0	0	0	2	0	0	0	0
		Macrochaetus danneeli	0	0	0	0	2	0	0	0	0	0	0	0
	Trochosphaeridae	*Horaella sp.*	0	0	0	0	0	0	0	0	0	0	2	0
ARTHROPODA														
CRUSTACEA														
Maxillopoda														
Calanoida	**Centropagidae**	*Eodiaptomus lumholtzi*	0	0	0	0	0	0	0	0	0	0	0	4
Cyclopoida		Cyclopoid copepodite	3	2	3	3	3	3	3	2	2	0	0	0
		Cyclopoid nauplii	2	1	3	3	4	4	0	2	2	4	4	3
	Cyclopidae	*Ectocyclops* cf. *phaleratus*	0	0	0	0	0	0	0	0	0	0	0	3
		Eucyclops australiensis	0	0	0	0	0	0	0	0	2	0	0	0
		Mesocyclops darwini	0	0	0	2	0	0	0	3	0	0	0	0
		Mesocyclops notius	1	0	2	0	0	0	0	0	0	2	2	4
		Microcyclops varicans	3	0	2	0	0	0	0	0	2	0	2	1
		Paracyclops sp. 5 (SAP)	0	0	0	0	0	0	0	0	0	0	2	0
		Thermocyclops affinis	0	0	0	0	0	0	0	0	0	0	2	0
		Tropocyclops confinis confinis	3	4	3	2	4	2	3	2	0	4	4	0
Harpacticoida		Harpacticoida sp.	0	0	0	0	0	0	1	0	0	0	0	0
Branchiopoda														
Diplostraca	**Chydoridae**	*Chydorus* sp.	0	0	0	0	0	0	0	0	2	0	0	0
	Daphniidae	*Ceriodaphnia* sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Simocephalus heilongjiangensis	0	0	0	0	0	0	0	0	0	0	0	1
	Macrothricidae	*Macrothrix spinosa*	0	0	3	0	0	0	0	0	0	0	0	0
	Ilyocryptidae	*Ilyocryptus* sp.	0	0	1	0	0	0	0	0	0	0	0	0
Ostracoda														
Podocopida	**Candonidae**	*Candonopsis tenuis*	1	0	1	0	0	0	0	0	0	0	0	0
	Cyprididae	Cyprididae `sp. Biologic-OSTR006`	0	0	0	0	0	0	0	1	0	0	3	3
		Bennelongia tirigie	2	0	0	0	0	0	0	0	0	0	0	0
		Cypretta sp. `BOS861`	1	0	2	0	0	0	0	0	0	0	0	0
		Cypretta sp. `PSW074`	0	0	0	0	0	0	0	0	0	0	1	2
		Cypridopsis `sp. Biologic-OSTR011`	0	0	0	0	0	0	0	1	0	0	0	0
		Cypridopsis sp. `BOS1401`	0	0	0	0	0	0	0	1	0	0	0	0
		Diacypcris sp.	0	0	0	0	0	0	0	0	3	0	0	0

			Within Study Area						Reference					
Phylum/ Class/ Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
		Ilyodromus sp.	0	0	0	0	0	0	0	0	1	0	0	0
		Sarscypridopsis sp.	0	0	0	0	0	0	0	0	2	0	0	3
		Stenocypris major	2	0	0	0	0	0	0	1	0	0	0	0
	Limnocytheridae	*Limnocythere* sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Limnocythere dorsosicula	2	0	2	0	0	0	0	0	0	0	0	0
	Darwinulidae	*Vestalenula* sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Vestalenula marmonieri	0	0	1	0	0	0	0	0	0	0	0	0
		Vestalenula matildae	0	0	0	0	0	0	0	0	0	0	1	0
		Taxa richness	**24**	**11**	**15**	**17**	**16**	**10**	**13**	**22**	**12**	**16**	**20**	**15**

Wet 2021

			Within Study Area						Reference					
Phylum/ Class/ Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
PROTISTA		Testate Amoeba	2	2	0	0	0	0	1	0	0	0	0	0
CILIOPHORA		Ciliate indet.	0	0	0	0	0	0	0	1	0	0	0	0
Prostomatea														
Prorodontida	**Colepidae**	*Coleps* sp.	2	1	2	0	2	0	0	2	0	0	0	2
Spirotrichea		Hypotrichia sp.	0	0	0	2	0	0	0	2	0	0	0	0
ROTIFERA		Unidentified Rotifera	1	1	2	0	1	3	2	2	0	0	0	0
Bdelloidea		Bdelloidea spp. indet.	1	0	2	2	2	0	2	2	0	0	0	2
Monogononta														
Ploima	**Brachionidae**	*Anuraeopsis* sp.	1	0	1	0	0	0	0	0	0	0	0	0
		Anuraeopsis cf. *navicula*	1	0	0	0	0	0	0	0	0	0	0	0
		Brachionus angularis	2	0	0	1	0	0	2	2	0	0	0	0
		Keratella sp.	0	0	0	0	1	1	0	0	0	0	0	0
		Keratella valga	2	0	0	0	3	3	1	0	0	2	0	1
		Platyias quadricornis	0	0	1	0	0	0	0	0	0	0	0	0
	Epiphanidae	cf. *Epiphanes* sp.	0	0	1	0	0	0	0	0	0	0	0	0
	Euchlanidae	*Euchlanis sp.*	0	0	0	0	0	0	0	0	0	0	0	1
	Hexarthridae	*Hexarthra* sp.	0	0	0	0	0	3	0	0	0	0	0	0
	Lecanidae	*Lecane* sp.	0	0	0	1	2	0	0	1	0	0	0	0
		Lecane benjamini	0	1	0	0	0	0	0	0	0	0	0	0
		Lecane cf. *bulla*	2	2	2	2	2	2	0	0	0	0	0	1
		Lecane cf. decipiens	0	0	3	0	0	0	2	2	0	0	0	0
		Lecane cf. elocharis	0	0	1	0	0	0	0	0	0	0	0	0
		Lecane cf. *hamata*	2	0	0	2	1	0	0	2	0	0	0	0
		Lecane cf. *hastata*	0	0	0	0	0	0	0	0	0	0	0	1
		Lecane cf. *opias*	0	2	0	1	2	0	0	0	0	0	0	0
		Lecane cf. *patella*	0	1	0	0	0	0	0	0	0	0	0	0
		Lecane cf. *sinuata*	1	0	0	0	0	0	0	0	0	0	0	0
		Lecane ungulata	0	0	0	0	0	0	0	0	0	0	0	1
	Lepadellidae	*Colurella* sp.	0	1	0	0	0	0	0	0	0	0	0	0
		Colurella cf. *uncinta*	2	0	3	2	2	0	2	1	0	0	0	0
		Colurella uncinata	0	0	0	0	0	0	0	0	0	0	1	0
		Lepadella sp.	0	1	2	2	0	0	2	2	0	0	0	1
		Lepadella cf. *ovalis*	2	0	0	2	0	0	1	3	0	0	0	0
		Squatinella sp.	0	0	0	0	0	0	0	1	0	0	0	0
	Notommatidae	cf. *Cephalodella* sp.	0	0	1	0	0	0	0	0	0	0	0	0
		cf. *Monommata* sp.	0	0	0	0	0	0	0	1	0	0	0	0
	Synchaetidae	*Polyarthra sp.*	1	0	0	0	3	4	1	0	0	0	0	0
		Polyarthra cf. *dolichoptera*	0	0	0	0	0	0	0	0	0	1	0	0
	Proalidae	*Proales sp.*	0	2	0	2	2	0	1	0	0	0	0	0

Phylum/ Class/ Order	Family	Lowest taxon	Within Study Area						Reference					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	SS	RW
	Testudinellidae	cf. *Testudinella* sp.	1	0	0	0	0	0	0	0	0	0	0	0
	Trichocercidae	*Trichocerca* sp.	0	0	0	0	0	0	1	1	0	1	0	0
		Trichocerca cf. *flagellata*	0	0	0	0	0	2	0	0	0	0	0	0
		Trichocerca cf. *bicristata.*	0	0	0	0	0	4	0	0	0	1	2	0
	Trichotriidae	*Macrochaetus danneeli*	0	0	0	1	0	0	0	0	0	0	0	0
CRUSTACEA														
Maxillopoda														
Cyclopoida		Cyclopoid copepodite	3	2	2	2	0	0	3	2	2	0	2	1
		Cyclopoid nauplii	2	2	2	2	4	5	2	3	1	2	2	2
	Cyclopidae	Mesocyclops sp.	0	0	0	0	0	3	0	0	0	0	0	0
		Mesocyclops brooksi	0	0	0	0	0	3	2	0	0	0	0	0
		Mesocyclops darwini	0	3	3	3	2	0	0	3	0	0	0	0
		Mesocyclops notius	3	0	3	0	0	0	1	0	0	3	3	3
		Microcyclops varicans	3	0	0	3	3	3	2	3	0	0	2	3
		cf. Paracyclops sp.	0	0	0	0	0	0	2	0	0	0	0	0
		Thermocyclops sp.	0	0	0	0	2	0	0	0	0	0	0	0
		Thermocyclops decipiens	0	0	0	0	4	4	0	0	0	0	0	0
		Tropocyclops confinis confinis	3	1	1	0	5	5	0	0	0	1	2	0
Branchiopoda														
Diplostraca	**Chydoridae**	*Alona* sp.	1	0	0	0	0	3	0	2	0	0	0	0
		Ephemeroporus cf. *barroisi*	2	0	0	0	0	0	0	2	0	0	0	0
	Daphniidae	*Ceriodaphnia sp.*	0	0	0	0	4	4	0	0	0	0	0	0
	Moinidae	*Moina* cf. *micrura*	0	0	0	0	0	2	0	0	0	0	0	0
	Sididae	*Daphniasoma* cf. *unguiculatum*	0	0	0	0	2	0	0	0	0	0	0	0
Ostracoda		Ostracoda sp. indet.	2	0	0	0	0	0	0	0	0	0	0	0
Podocopida	**Cyprididae**	*Bennelongia* \`sp. Biologic-OSTR026\`	1	0	0	0	0	0	0	0	0	0	0	0
		Cypridopsis funebris	2	0	0	0	0	0	0	0	0	0	0	0
		Cypridopsis sp.	0	0	0	0	1	0	0	0	0	0	0	0
		Cypridopsis \`sp. Biologic-OSTR011\`	0	0	0	0	0	0	0	1	0	0	0	0
		Cyprididae \`sp. Biologic-OSTR014\`	0	0	1	1	0	1	0	0	0	0	0	0
		Cyprididae \`sp. Biologic-OSTR015\`	1	0	0	0	0	0	0	0	0	0	0	0
		Cyprididae \`sp. Biologic-OSTR019\`	0	0	0	0	1	1	0	0	0	0	0	0
		Cyprididae \`sp. Biologic-OSTR006\`	1	1	0	0	0	1	0	1	0	0	0	0
		Ilyodromus sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Stenocypris major	0	0	1	0	0	0	0	0	0	0	0	0
	Candonidae	*Candonopsis* sp.	2	0	0	0	0	0	0	0	0	0	0	0
		Candonidae \`sp. Biologic-OSTR009\`	1	1	0	0	0	0	0	0	0	0	0	0
		Taxa richness	**28**	**15**	**19**	**17**	**22**	**20**	**18**	**24**	**2**	**7**	**7**	**12**

Appendix F: Hyporheic taxonomic list

Values are log abundances (i.e., 1=1 individual, 2 = 2-10, 3 = 11-100, 4 = 101-1000, and so on).

Dry 2020

			Within Study Area					Reference sites				
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MACREF2**	**WWS**	**BENS**	**SS**	**RW**
CNIDARIA												
Hydrozoa												
Anthoathecata	**Hydridae**	*Hydra* sp.	0	0	0	0	0	0	0	0	0	1
NEMATODA		Nematoda sp.	0	0	2	0	0	2	0	0	0	2
PLATYHELMINTHES		Turbellaria sp.	0	0	0	3	0	3	0	3	0	0
MOLLUSCA												
Gastropoda												
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	0	0	0	0	0	0	0	1	0	0
	Planorbidae	*Gyraulus* sp.	0	0	0	0	0	0	0	0	0	1
ANNELIDA												
Polychaeta		Polychaeta sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	1
Oligochaeta												
Tubificida	**Naididae**	Naididae sp. (imm./dam.)	1	0	0	0	0	0	2	2	0	0
		Naidinae sp. (imm./dam.)	0	0	0	0	0	0	0	0	2	3
		Allonais pectinata	0	0	0	0	0	0	0	0	0	2
		Allonais ranauana	0	0	0	0	0	0	0	0	0	3
		Dero nivea	0	0	0	0	2	0	0	0	0	0
		Pristina sp. (imm./dam.)	0	0	0	0	0	0	3	0	0	2
		Pristina aequiseta	3	0	0	0	0	0	0	0	0	3
		Pristina jenkinae	0	0	0	0	0	0	0	0	0	2
		Pristina leidyi	0	0	0	0	0	0	0	0	3	0

			Within Study Area					Reference sites				
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MACREF2**	**WWS**	**BENS**	**SS**	**RW**
		Pristina longiseta	2	0	3	0	3	0	0	0	0	0
		Pristina nr. *osborni*	0	0	1	0	2	3	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	0	2	3
		Antarctodrilus sp.	0	0	0	0	0	2	0	0	0	0
Hirudinida		Hirudinea sp.	0	0	0	1	0	0	0	0	0	0
ARTHROPODA												
CHELICERATA												
Arachnida		Acarina sp. (imm./dam.)	0	1	0	0	0	0	0	1	0	2
Mesostigmata		Mesostigmata sp.	0	0	0	0	0	1	0	0	3	2
Sarcoptiformes		Oribatida sp.	0	0	0	2	0	0	0	0	0	2
Trombidiformes		Trombidioidea sp. (imm./dam.)	0	2	0	0	0	0	0	0	1	0
	Halacaridae	Halacaridae sp.	0	0	0	0	0	2	0	0	0	0
	Hydrachnidae	Hydrachnidae sp.	0	1	0	0	0	0	0	0	0	0
	Hydryphantidae	*Wandesia* sp.	0	0	0	0	0	0	1	0	0	0
	Limnesiidae	*Limnesia* sp.	0	1	0	0	0	0	0	0	0	0
	Momoniidae	*Hesperomomonia humphreysi*	0	0	0	0	0	0	1	0	0	0
CRUSTACEA												
Branchiopoda												
Diplostraca												
	Chydoridae	*Alona rigidicaudis*	0	0	0	0	0	0	0	0	0	1
Ostracoda												
Podocopida	**Candonidae**	Candonidae `sp. Biologic-OSTR010`	0	0	0	0	0	0	3	0	0	0
		Candonidae `sp. Biologic-OSTR009`	2	0	0	0	0	0	0	0	0	0
		Candonopsis tenuis	0	2	3	0	0	0	0	0	0	0
	Cyprididae	Cyprididae `sp. Biologic-OSTR006`	0	0	0	0	0	0	0	0	0	4
		Cypridopsis sp. `BOS1401`	1	2	0	0	0	0	0	0	0	0
	Darwinulidae	*Penthesilenula brasiliensis*	0	0	0	0	0	1	0	0	0	0
		Vestalenula matildae	0	0	0	0	0	0	0	0	2	0

			Within Study Area					Reference sites				
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MACREF2**	**WWS**	**BENS**	**SS**	**RW**
	Limnocytheridae	*Gomphodella alexanderi*	0	2	0	0	0	0	0	0	0	0
		Limnocythere dorsosicula	0	0	2	0	0	0	0	0	0	0
Maxillopoda												
Cyclopoida	**Cyclopidae**	Cyclopidae sp. (imm./dam.)	0	0	0	0	0	0	2	0	0	0
		Diacyclops humphreysi s.l.	0	1	0	0	0	2	0	0	0	0
		Ectocyclops cf. *phaleratus*	0	0	0	0	0	0	0	0	0	3
		Ectocyclops phaleratus	0	2	3	0	0	0	2	0	0	0
		Mesocyclops notius	0	0	0	0	0	0	1	0	0	0
		Microcyclops varicans	4	2	3	0	0	0	1	2	2	2
		Paracyclops intermedius	0	2	0	0	0	2	0	0	0	0
Harpacticoida	**Parastenocarididae**	*Parastenocaris* sp.	0	0	0	0	0	0	0	0	1	1
Malacostraca												
Bathynellacea	**Parabathynellidae**	*Atopobathynella* sp.	0	0	0	0	0	0	0	0	3	0
Amphipoda	**Paramelitidae**	Paramelitidae sp.	0	0	0	0	0	1	0	0	0	3
		Paramelitidae `sp. Biologic-AMPH024`	0	0	0	0	0	0	3	0	0	0
		Chydaekata sp. E	0	0	0	0	0	0	1	0	0	0
HEXAPODA												
Entognatha												
Symphypleona	**Sminthuridae**	Sminthuridae sp.	0	0	0	0	0	0	0	0	2	0
Entomobryomorpha		Entomobryoidea sp.	2	1	0	0	0	1	1	0	0	2
Insecta												
Coleoptera	**Carabidae**	Carabidae sp. (L)	1	0	0	0	0	0	0	0	0	0
		Carabidae sp.	0	0	0	0	2	0	0	3	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	0	0	1
	Georissidae	*Georissus* sp.	0	0	0	0	0	0	0	2	0	2
	Heteroceridae	*Heterocerus* sp.	0	0	0	0	0	0	0	2	0	0
	Hydraenidae	*Hydraena* sp.	2	0	0	1	0	0	2	3	0	3
		Limnebius sp.	0	0	0	0	0	0	0	0	0	2
		Ochthebius sp.	0	0	0	0	2	0	0	3	0	0

Phylum/Class/Order	Family	Lowest taxon	Within Study Area MarC1	MarC2	MarC3	MarC4	MarC5	Reference sites MACREF2	WWS	BENS	SS	RW
	Hydrophilidae	Hydrophilidae sp. (L) (imm./dam.)	1	0	0	2	0	0	1	0	1	0
		nr. *Anacaena* sp.	2	2	0	0	2	0	0	0	0	0
		Chaetarthria nigerrima (L)	1	1	0	0	0	0	3	0	3	3
		Chaetarthria nigerrima	0	0	0	0	0	0	0	1	2	1
		Coelostoma fabricii	0	0	0	0	0	0	0	1	0	0
		Enochrus sp. (L)	0	0	2	0	0	0	2	0	0	0
		Helochares sp. (L)	0	0	0	0	0	0	0	0	1	2
		Paracymus sp. (L)	0	0	0	2	0	0	1	0	0	0
	Limnichidae	Limnichidae sp. A	0	1	0	0	1	0	0	0	0	0
		Limnichidae sp. B	0	0	2	0	1	0	1	3	0	0
	Ptiliidae	Ptiliidae sp.	0	0	1	0	0	0	0	3	2	0
	Scirtidae	Scirtidae sp. (L)	2	2	0	2	3	3	0	0	0	2
	Staphylinidae	Staphylinidae sp.	1	0	1	3	1	1	0	3	2	0
Diptera	**Ceratopogonidae**	Ceratopogonidae sp. (P)	2	1	0	3	2	0	2	2	2	1
		Ceratopogoninae sp.	3	3	3	3	4	3	3	4	3	3
		Dasyhelea sp.	1	2	2	2	2	1	3	2	3	3
		Forcipomyiinae sp.	0	0	0	0	0	0	0	0	0	1
	Chironomidae	Chironomidae sp. (P)	0	0	0	0	0	0	0	0	0	1
	Chironominae											
	Chironomini	*Chironomus* aff. *alternans*	2	2	0	0	0	0	0	0	0	0
		Cryptochironomus griseidorsum	0	0	0	1	0	0	0	0	0	0
		Demicryptochironomus (*Irmakia*) sp.	0	0	0	0	0	0	0	0	0	2
		Polypedilum sp.	0	0	0	0	2	0	0	0	0	2
		Polypedilum (*Pentapedilum*) *leei*	0	0	0	0	1	0	0	0	0	0
		Polypedilum nubifer	0	0	0	0	0	0	0	3	0	0
	Tanytarsini	*Paratanytarsus* sp.	0	0	0	0	0	0	0	0	2	0
		Rheotanytarsus sp.	0	0	0	0	0	0	0	0	1	3
		Tanytarsus sp.	3	3	0	3	3	0	2	3	3	3
	Orthocladiinae	nr. *Gymnometriocnemus* sp.	0	0	0	0	0	3	1	0	1	0

Phylum/Class/Order	Family	Lowest taxon	MarC1	MarC2	MarC3	MarC4	MarC5	MACREF2	WWS	BENS	SS	RW
			Within Study Area					Reference sites				
	Tanypodinae	?*Australopelopia* sp.	0	0	0	0	0	0	0	0	1	0
		Larsia ?albiceps	0	2	0	0	0	0	2	0	2	3
		Paramerina sp. 1	2	2	2	0	2	1	2	0	3	2
		Procladius sp.	0	0	0	0	2	0	0	4	0	0
	Culicidae	*Anopheles* sp.	0	0	0	0	0	0	1	0	0	3
	Dolichopodidae	Dolichopodidae sp.	0	0	0	2	0	0	0	3	0	0
	Ephydridae	Ephydridae sp.	0	0	0	0	0	1	0	0	0	3
	Sciaridae	Sciaridae sp.	0	0	2	0	0	2	0	0	0	0
	Stratiomyidae	Stratiomyidae sp.	0	2	0	0	0	0	0	0	0	1
	Thaumaleidae	Thaumaleidae sp.	0	0	0	0	0	0	1	0	0	0
	Tipulidae	Tipulidae sp.	0	0	0	0	0	0	0	0	3	2
Ephemeroptera	**Caenidae**	Caenidae sp. (imm./dam.)	0	1	0	0	3	0	0	0	0	2
		Tasmanocoenis sp. P/*arcuata*	0	0	0	0	2	0	0	0	0	2
Hemiptera	**Gelastocoridae**	*Nerthra* sp.	0	0	0	0	0	0	0	0	1	0
	Hebridae	*Hebrus axillaris*	0	0	0	1	0	0	0	2	0	0
Lepidoptera	**Crambidae**	Acentropinae sp. (imm./dam.)	0	0	0	0	0	0	2	0	0	0
Thysanoptera		Thysanoptera sp.	0	0	0	0	0	0	0	1	0	0
		Taxa richness	**20**	**25**	**15**	**15**	**20**	**19**	**28**	**24**	**28**	**46**

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Phylum/Class/Order	Family	Lowest taxon	Within Study Area MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	Reference sites MACREF2	WWS	BENS	SS	RW
MOLLUSCA													
Gastropoda													
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	0	0	0	1	0	0	0	0	0	0	0
	Planorbidae	*Gyraulus* sp.	0	0	0	2	0	0	0	0	0	0	0
ANNELIDA													
Polychaeta													
	Aeolosomatidae	Aeolosomatidae sp.	0	0	0	0	0	0	0	0	0	0	2
Oligochaeta													
Tubificida	**Naididae**	Naididae sp. (imm./dam.)	3	2	0	0	0	0	0	0	0	0	0
		Naidinae sp. (imm./dam.)	0	0	3	2	3	0	0	0	0	0	0
		Allonais pectinata	0	1	0	0	0	0	0	0	0	0	0
		Allonais ranauana	0	2	0	0	0	0	0	0	0	0	0
		Chaetogaster sp.	0	0	0	0	0	2	0	0	0	0	1
		Pristina sp. (imm./dam.)	0	2	3	2	0	0	0	0	0	0	0
		Pristina aequiseta	3	0	3	0	3	0	2	0	2	2	3
		Pristina jenkinae	3	1	0	0	0	0	0	0	0	0	0
		Pristina leidyi	0	1	0	1	2	0	0	0	0	0	0
		Pristina longiseta	2	2	2	2	3	3	0	0	0	0	3
		Pristina nr. *osborni*	2	0	2	0	0	0	2	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	0	0	2	0
		Antarctodrilus sp.	0	0	0	0	0	0	0	0	0	1	0
ARTHROPODA													
CHELICERATA													
Arachnida													
Mesostigmata		Mesostigmata sp.	0	0	1	2	0	0	2	0	0	1	2
Sarcoptiformes		Oribatida sp.	1	0	1	3	2	0	3	0	0	3	0
Trombidiformes		Trombidioidea sp.	0	1	0	0	0	0	0	0	0	0	2
	Anisitsiellidae	*Rutacarus* sp.	0	0	0	2	1	0	0	0	1	0	0
	Halacaridae	Halacaridae sp.	0	0	0	0	2	0	1	0	0	2	0
	Hydryphantidae	*Wandesia* sp.	1	0	0	0	1	0	1	0	0	0	0
	Limnesiidae	*Limnesia* sp. \`solida group\`	0	1	0	0	0	0	0	0	1	0	0
	Limnocharidae	Limnocharidae sp.	0	1	0	0	0	0	0	0	0	0	0
	Mideopsidae	*Guineaxonopsis* sp.	2	2	0	2	0	0	0	0	0	0	0
	Unionicolidae	Unionicolidae sp.	0	0	1	0	0	0	0	0	0	0	0
CRUSTACEA													
Branchiopoda													
Diplostraca		Cladocera sp. (imm./dam.)	0	0	0	1	0	1	0	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Within Study Area MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	Reference sites MACREF2	WWS	BENS	SS	RW
Ostracoda													
Podocopida	**Candonidae**	Candonidae sp. (imm./dam.)	0	0	0	0	2	0	0	0	0	0	0
		Candonopsis tenuis	0	0	4	0	0	0	0	0	0	0	0
		Candonidae `sp. Biologic-OSTR009`	2	0	0	0	0	0	0	0	0	0	0
	Cyprididae	Cyprididae sp.	0	0	0	0	0	0	2	0	0	0	0
		Bennelongia sp.	2	0	0	0	1	0	0	0	0	0	0
		Cypridopsis sp.	2	0	0	0	0	0	0	0	0	0	0
		Ilyodromus sp.	0	0	2	1	0	0	0	0	0	0	0
		Cyprididae `sp. Biologic-OSTR006`	3	0	0	2	0	0	0	0	0	0	0
	Darwinulidae	*Vestalenula* sp.	0	0	0	0	0	0	2	0	0	0	0
Maxillopoda													
Cyclopoida	**Cyclopidae**	*Diacyclops humphreysi* s.l.	0	0	0	0	0	0	1	0	0	2	0
		Ectocyclops phaleratus	2	0	0	0	0	0	0	0	0	0	0
		Mesocyclops notius	0	2	0	0	0	0	0	0	2	0	0
		Microcyclops varicans	3	2	4	4	4	1	0	2	3	0	2
		Paracyclops sp.	0	2	0	0	0	0	1	0	0	0	0
		Thermocyclops sp.	0	0	0	0	0	0	0	0	2	0	0
Harpacticoida	**Canthocamptidae**	*Elaphoidella* sp.	0	0	0	2	0	0	0	0	0	1	0
	Parastenocarididae	*Parastenocaris* sp.	0	0	0	0	1	0	0	0	0	0	2
Malacostraca													
Bathynellacea	**Parabathynellidae**	*Atopobathynella* sp.	0	0	0	0	0	0	0	0	0	1	0
Amphipoda	**Paramelitidae**	Paramelitidae `sp. Biologic-AMPH049`	0	0	0	0	0	0	0	0	0	2	0
		Chydaekata sp. E	0	0	0	0	0	0	0	3	0	0	0
HEXAPODA													
Entognatha													
Entomobryomorpha		Entomobryoidea sp.	0	0	0	1	0	0	0	0	0	0	3
Poduromorpha		Poduroidea sp.	0	0	0	0	0	0	0	0	2	0	0
Symphypleona		Symphypleona sp.	0	0	0	0	0	0	0	0	2	3	3
Insecta													
Coleoptera	**Carabidae**	Carabidae sp.	0	0	0	0	0	0	0	0	0	1	0
	Dytiscidae	Bidessini sp. (L)	0	1	0	1	0	0	0	0	0	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	1	0	0	0	0	0	0	0
	Heteroceridae	*Heterocerus* sp. (L)	0	0	0	2	0	0	1	0	0	0	0
	Hydraenidae	Hydraenidae sp. (L)	0	0	0	2	1	3	0	0	0	0	3
		Hydraena sp.	1	2	2	3	3	0	0	0	2	0	0
		Limnebius sp.	0	0	3	0	0	1	0	0	0	0	0
		Ochthebius sp.	0	1	0	1	0	0	0	0	0	0	0
	Hydrophilidae	Hydrophilidae sp. (L) (imm./dam.)	2	0	0	0	1	0	0	0	0	2	0
		Berosus sp. (L)	0	0	0	0	1	0	0	0	0	0	0
		Chaetarthria nigerrima (L)	0	0	0	0	1	2	0	0	0	0	0

			Within Study Area						Reference sites				
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**WWS**	**BENS**	**SS**	**RW**
		Enochrus sp. (L)	0	0	0	0	0	0	0	1	1	2	0
		Helochares sp. (L)	2	0	2	2	2	3	0	0	0	0	0
		Helochares sp.	0	3	0	0	0	0	0	0	0	0	0
		nr. *Anacaena* sp.	0	1	0	0	0	0	0	0	0	0	0
		Paracymus sp. (L)	1	1	0	0	0	3	1	0	0	0	0
		Paracymus spenceri	0	0	1	2	0	0	0	0	0	0	0
	Limnichidae	*Limnichidae* sp. B	1	2	0	1	2	0	0	0	0	0	1
	Ptiliidae	Ptiliidae sp.	0	0	0	0	0	0	0	0	0	0	3
	Scirtidae	Scirtidae sp. (L)	0	0	0	3	3	3	1	1	0	0	0
	Staphylinidae	Staphylinidae sp.	0	1	0	1	2	0	0	0	0	0	1
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	0	2	0	0	0	0	0	0	0	2	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	0	1	0	0	2	2	0	0	2	1
		Ceratopogoninae sp.	3	3	3	3	3	3	3	0	2	2	3
		Dasyhelea sp.	2	2	3	1	2	1	0	0	1	0	0
		Forcipomyiinae sp.	1	3	0	0	0	0	0	0	0	0	0
	Chironomidae												
	Chironominae												
	Chironomini	Chironomini sp. (imm./dam.)	0	0	0	0	0	1	0	0	0	0	0
		Cryptochironomus griseidorsum	0	0	0	0	0	2	0	0	0	0	0
		Dicrotendipes sp.	0	0	1	0	0	0	1	0	0	0	0
		Polypedilum sp.	0	0	0	0	0	0	0	0	2	0	0
		Polypedilum sp. K1	1	0	0	0	0	3	0	0	0	0	0
	Tanytarsini	*Cladotanytarsus* sp.	0	0	2	2	0	0	0	0	0	0	0
		Paratanytarsus sp.	0	1	3	2	0	2	0	0	1	0	0
		Tanytarsus sp.	3	2	2	2	2	2	0	0	1	0	0
	Orthocladiinae	nr. *Parametriocnemus* sp.	0	0	0	0	0	0	0	0	1	0	0
	Tanypodinae	?*Australopelopia* sp.	2	3	0	0	3	0	0	0	1	2	0
		Larsia ?albiceps	2	0	0	0	3	2	0	1	2	0	0
		Paramerina sp. 1	2	3	2	3	4	0	0	0	3	0	0
		Procladius sp.	0	0	0	2	2	1	0	0	2	0	0
		Tanypodinae sp. BES10593	3	0	0	0	0	0	0	1	0	0	1
	Culicidae	*Anopheles* sp.	0	0	0	0	0	1	0	0	1	0	0
	Dolichopodidae	Dolichopodidae sp.	0	0	0	0	0	1	0	0	0	0	0
	Scatopsidae	Scatopsidae sp.	0	0	0	0	0	0	1	0	0	0	0
	Stratiomyidae	Stratiomyidae sp.	0	0	0	0	2	0	0	0	1	0	0
	Tipulidae	Tipulidae sp.	0	2	0	0	1	2	0	0	0	0	3
Ephemeroptera	**Baetidae**	Baetidae sp. (imm./dam.)	0	0	0	0	0	1	0	0	2	0	0
	Caenidae	Caenidae sp. (imm./dam.)	1	0	0	0	0	2	0	0	2	0	0
Hemiptera	**Hebridae**	*Hebrus axillaris*	0	0	0	2	1	0	0	0	0	0	0
Lepidoptera	**Crambidae**	Acentropinae sp. (imm./dam.)	0	0	0	2	0	0	0	0	0	0	0
Odonata		Zygoptera sp. (imm./dam.)	0	0	0	0	0	0	0	0	2	0	0

Phylum/Class/Order	Family	Lowest taxon	Within Study Area MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	Reference sites MACREF2	WWS	BENS	SS	RW
		Anisoptera sp. (imm./dam.)	1	2	0	0	2	1	0	0	0	0	0
Trichoptera		Trichoptera sp. (imm./dam.)	0	0	0	0	0	0	0	0	2	0	0
	Ecnomidae	*Ecnomus* sp. (imm./dam.)	0	0	0	0	0	0	0	0	2	0	0
	Hydroptilidae	*Hellyethira* sp.	0	1	0	0	0	0	0	0	0	0	0
		Taxa richness	**30**	**33**	**23**	**36**	**32**	**26**	**17**	**6**	**27**	**19**	**18**

Appendix G: Macroinvertebrate taxonomic list

Values are log abundances (i.e., 1=1 individual, 2 = 2-10, 3 = 11-100, 4 = 101-1000, and so on).

Dry 2020

			Within Study Area						Reference sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
CNIDARIA														
Hydrozoa														
Anthoathecata	**Hydridae**	*Hydra* sp.	0	2	0	0	0	0	0	0	1	0	0	0
PLATYHELMINTHES		Turbellaria sp.	0	0	0	0	1	0	0	0	0	0	0	1
NEMATODA		Nematoda sp.	0	0	0	0	0	0	0	0	0	0	0	1
NEMATOMORPHA														
Gordioidea		Gordioidea sp.	0	1	0	0	0	0	0	0	0	0	0	0
MOLLUSCA														
Gastropoda														
Cerithimorpha	**Thiaridae**	Thiaridae sp.	0	0	0	0	0	0	0	0	0	0	1	0
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	3	3	3	3	3	2	3	0	0	3	0	0
	Planorbidae	*Ferrissia petterdi*	0	0	0	0	0	0	0	2	0	2	0	1
		Gyraulus sp.	2	2	2	1	3	1	0	3	0	3	2	1
ANNELIDA														
Polychaeta	**Aeolosomatidae**	Aeolosomatidae sp.	0	0	0	0	0	1	0	0	0	0	0	0
Oligochaeta														
Tubificida	**Naididae**	Naididae sp. (imm./dam.)	3	0	0	0	0	0	0	0	0	0	0	0
		Naidinae sp. (imm./dam.)	0	0	0	0	0	0	0	0	2	2	2	4
		Allonais pectinata	0	0	0	0	0	0	0	0	0	0	0	3
		Allonais ranauana	0	0	0	0	0	0	0	0	0	0	0	3
		Dero nivea	0	0	0	0	2	3	0	0	0	0	0	0
		Nais variabilis	0	0	0	0	0	0	0	0	2	0	0	3
		Pristina sp. (imm./dam.)	0	0	0	0	0	0	0	0	2	0	3	0
		Pristina ?proboscidea	3	0	0	0	0	0	0	0	0	0	0	0
		Pristina aequiseta	0	2	0	0	0	0	0	0	0	0	2	0
		Pristina jenkinae	0	0	1	2	0	0	0	0	0	0	0	0
		Pristina longiseta	0	3	3	3	0	2	3	3	3	0	3	0
		Pristina nr. *osborni*	0	0	0	0	0	0	0	2	0	0	0	0
Hirudinida		Hirudinea sp.	1	0	0	0	0	0	0	0	0	0	0	0
ARTHROPODA														
CHELICERATA														

Phylum/Class/Order	Family	Lowest taxon	Within Study Area						Reference sites					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	SS	RW
Arachnida														
Sarcoptiformes		Oribatida sp.	1	0	2	0	0	0	0	0	0	0	0	0
Trombidiformes		Prostigmata sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	2	0	0
		Trombidioidea sp. (imm./dam.)	0	0	0	2	0	0	0	0	0	0	0	0
	Arrenuridae	*Arrenurus* sp. (imm./dam.)	1	0	0	2	2	3	0	0	0	0	0	1
		Arrenurus ensifer	0	0	0	0	0	0	0	0	1	0	0	0
	Eylaidae	*Eylais* sp.	0	0	0	2	0	0	1	0	0	0	0	0
	Hydrachnidae	*Hydrachna* sp.	0	0	0	3	0	3	0	1	0	0	0	0
	Hydrodromidae	*Hydrodroma* sp.	0	0	3	2	0	3	0	0	1	0	0	0
	Hydryphantidae	Hydryphantidae sp.	0	0	0	0	0	0	0	0	0	1	0	0
		Hydryphantes sp.	0	0	0	0	0	0	0	0	0	0	1	0
	Hygrobatidae	*Aspidiobates pilbara*	0	1	2	0	0	0	0	0	0	0	0	0
		Australiobates sp.	0	0	0	0	0	2	0	2	0	1	0	0
		Coaustraliobates sp.	0	0	0	0	2	0	0	0	0	0	0	0
		Coaustraliobates minor	0	0	0	0	0	0	0	0	0	2	0	0
	Limnesiidae	*Limnesia* sp.	0	2	3	0	2	3	0	0	0	2	0	0
		Limnesia sp. 4	2	2	2	3	3	3	1	3	0	2	2	0
	Limnocharidae	*Limnochares* sp.	0	0	0	2	0	2	1	0	0	0	0	0
	Momoniidae	*Momoniella* sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Momoniella australica	0	0	0	0	0	0	1	0	0	0	0	0
	Oxidae	*Oxus* sp.	0	0	0	0	0	0	0	0	0	0	0	2
		Oxus orientalis	1	0	0	2	0	2	0	2	0	0	1	0
	Pionidae	*Piona* sp.	0	0	0	0	2	0	0	0	0	0	0	0
	Trombidiidae	Trombidiidae sp.	0	0	0	0	0	0	0	0	0	0	1	0
	Unionicolidae	*Neumania* sp.	0	2	0	0	3	2	0	2	0	0	0	1
		Recifella sp.	0	0	2	0	0	3	0	0	0	0	0	0
		Unionicola sp.	0	0	0	0	0	2	0	0	0	0	0	0
CRUSTACEA														
Malacostraca														
Amphipoda	**Paramelitidae**	*Chydaekata* sp. E	0	0	0	0	0	0	0	0	2	0	0	0
Decapoda	**Parastacidae**	*Cherax quadricarinatus*	0	0	0	0	0	0	0	0	2	0	0	0
HEXAPODA														
Entognatha														
Entomobryomorpha		Entomobryoidea sp.	0	0	0	0	0	0	0	1	0	0	0	1
Insecta														
Coleoptera	**Curculionidae**	Curculionidae sp. (L)	0	0	0	0	0	0	0	0	0	0	1	0
	Dytiscidae	*Allodessus bistrigatus*	0	1	0	0	1	0	0	0	0	0	0	0
		Austrodytes insularis	0	0	0	1	0	0	0	0	0	0	0	0
		Austrodytes plateni	0	1	0	0	1	0	0	0	0	0	0	0
		Batrachomatus wingii	0	0	0	0	0	0	0	0	0	0	0	1
		Bidessini sp. (L)	0	0	0	0	0	0	0	0	0	0	2	0
		Copelatus irregularis	0	0	0	0	0	0	0	0	0	1	0	0

			Within Study Area						Reference sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
		Copelatus nigrolineatus	2	2	0	0	0	0	0	0	0	0	0	0
		Cybister tripunctatus	0	2	0	2	2	0	0	0	0	2	0	1
		Eretes australis	0	0	0	2	1	0	0	0	0	0	0	0
		Hydaticus consanguineus	0	0	0	0	2	0	0	0	0	0	0	2
		Hydroglyphus godeffroyi	0	0	1	1	0	0	0	0	0	0	0	0
		Hydroglyphus grammopterus	0	0	2	0	0	1	1	0	0	0	0	0
		Hydroglyphus leai	0	0	0	1	0	0	0	0	0	0	0	0
		Hydroglyphus orthogrammus	0	2	3	2	2	3	2	2	0	3	3	2
		Hydrovatus sp. (L)	2	0	0	0	0	0	0	0	0	0	1	0
		Hydrovatus opacus	1	0	0	0	0	0	0	0	0	0	0	0
		Hyphydrus sp. (L)	0	0	0	0	0	0	0	0	0	0	0	0
		Hyphydrus elegans	2	2	0	0	2	2	0	0	1	0	2	0
		Hyphydrus lyratus	2	2	2	2	2	2	0	0	1	0	0	0
		Laccophilus sharpi	2	0	0	0	0	0	0	0	0	0	0	0
		Limbodessus compactus	0	1	0	0	0	0	0	0	0	0	0	0
		Necterosoma sp. (L)	0	0	1	2	0	0	2	2	0	0	0	0
		Necterosoma regulare	0	0	0	2	0	2	0	0	0	2	0	0
		Neobidessodes denticulatus	0	2	0	2	2	1	2	2	0	0	0	0
		Platynectes decempunctatus var. *decempunctatus*	1	1	0	0	1	0	0	0	0	0	0	0
		Rhantaticus congestus	3	2	0	0	2	0	0	0	0	0	0	0
		Tiporus tambreyi	0	0	0	0	0	0	0	0	0	2	0	0
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	0	0	0	2	3
	Gyrinidae	*Dineutus australis*	0	0	0	2	0	0	0	0	1	0	0	0
		Macrogyrus sp. (L)	0	0	0	0	0	0	0	0	1	0	0	0
		Macrogyrus paradoxus	0	0	0	0	0	0	0	0	2	0	0	0
	Haliplidae	*Haliplus pilbaraensis*	2	0	0	1	0	0	0	0	0	0	0	0
	Hydraenidae	*Hydraena* sp.	3	2	2	1	1	1	0	3	0	3	2	0
		Limnebius sp.	2	0	3	2	1	2	1	0	0	2	1	0
		Ochthebius sp.	0	0	0	1	0	2	0	0	0	0	0	0
	Hydrochidae	*Hydrochus* sp. Group 2 'black'	0	0	0	1	0	0	0	0	0	0	0	0
		Hydrochus sp. P1	0	0	0	0	0	0	0	0	0	0	2	1
		Hydrochus eurypleuron	0	0	2	2	2	1	0	2	0	2	0	1
		Hydrochus interioris	0	0	2	0	0	0	0	0	0	0	1	1
		Hydrochus obscuroaeneus	0	0	2	1	0	0	0	2	0	1	0	0
	Hydrophilidae	*Anacaena horni*	0	2	0	0	1	0	1	2	0	2	0	0
		Berosus australiae	0	0	0	2	0	0	0	0	0	0	0	0
		Berosus dallasi	2	2	0	1	2	2	0	0	0	0	3	0
		Enochrus deserticola	2	0	0	0	0	1	0	1	0	0	0	0
		Helochares sp. (L)	0	0	0	0	0	0	1	0	0	0	1	2
		Helochares tatei	0	0	0	0	0	0	0	0	0	0	0	0
		Laccobius sp. (L)	0	0	0	0	0	0	1	0	0	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Within Study Area						Reference sites					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	SS	RW
		Paracymus sp. (L)	0	0	0	0	0	0	2	0	0	0	0	0
		Paracymus spenceri	2	0	2	3	0	1	2	2	0	2	2	2
		Regimbartia attenuata (L)	2	0	0	0	0	0	0	0	0	0	0	0
		Regimbartia attenuata	0	2	0	1	1	0	0	1	0	0	0	0
		Sternolophus sp. (L)	0	0	0	0	0	0	0	0	0	0	2	1
		Sternolophus immarginatus	0	0	0	0	0	0	0	0	0	0	0	1
		Sternolophus marginicollis	0	2	0	0	0	0	1	2	0	0	2	2
	Limnichidae	Limnichidae sp. B	0	0	0	0	0	0	1	0	0	0	0	0
	Ptiliidae	Ptiliidae sp.	0	0	0	0	0	0	1	0	0	0	0	0
	Scirtidae	Scirtidae sp. (L)	3	2	0	0	1	0	2	3	2	2	2	1
	Spercheidae	*Spercheus* sp. (L)	0	0	0	0	0	0	0	0	0	1	0	0
	Staphylinidae	Staphylinidae sp.	0	0	0	0	0	0	2	0	0	0	0	0
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	0	0	0	0	1	0	0	0	0	0	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	0	1	0	2	0	0	0	2	2	0	2	2
		Ceratopogoninae sp.	2	3	3	3	3	2	3	3	3	3	3	2
		Dasyhelea sp.	3	3	3	3	2	2	3	2	2	0	3	3
	Chironomidae	Chironomidae sp. (P)	0	1	0	1	2	2	2	2	1	1	0	2
	Chironominae													
	Chironomini	Chironomini sp. (imm./dam.)	0	0	0	0	0	0	2	0	0	0	0	0
		Chironomus aff. *alternans*	1	3	0	3	0	0	0	3	0	2	3	2
		Cladopelma curtivalva	0	0	2	0	0	0	0	0	0	0	0	0
		Cryptochironomus griseidorsum	0	0	0	0	0	0	2	0	0	1	1	0
		Dicrotendipes jobetus	0	0	0	0	2	0	0	0	0	0	0	0
		Dicrotendipes sp. 'CA1'	0	0	0	0	3	1	2	0	1	0	0	0
		Dicrotendipes sp. P4	0	0	0	0	1	0	0	0	2	0	0	0
		Kiefferulus intertinctus	0	0	0	0	0	0	0	0	0	1	0	0
		Parachironomus sp.	0	0	0	0	2	0	0	0	0	0	0	0
		Paracladopelma sp.	0	0	0	0	1	0	0	0	0	0	0	0
		Polypedilum sp.	0	0	0	0	0	0	2	0	0	0	0	0
		Polypedilum (*Pentapedilum*) *leei*	0	0	0	0	0	0	0	0	0	0	0	1
		Polypedilum sp. K1	0	0	0	0	0	0	0	3	0	2	0	0
		Stenochironomus watsoni	0	0	0	0	0	0	0	1	0	0	0	0
	Tanytarsini	Tanytarsini sp. (imm./dam.)	0	0	0	0	2	0	0	0	0	0	0	0
		Cladotanytarsus sp.	0	0	0	0	2	3	2	0	0	0	1	2
		Paratanytarsus sp.	0	2	0	0	2	3	0	0	0	0	2	3
		Stempellinella sp.	0	0	0	2	0	0	0	0	0	0	0	1
		Tanytarsus sp.	3	4	3	3	3	2	3	2	2	3	3	2
	Orthocladiinae	*Corynoneura* sp.	0	0	0	0	0	0	0	2	2	0	1	0
		Rheocricotopus sp.	0	0	0	0	0	0	1	0	1	0	2	1
		Thienemanniella sp.	0	0	0	0	0	0	2	0	0	0	1	1
	Tanypodinae	Pentaneurini sp. (imm./dam.)	0	0	0	0	0	0	0	3	0	0	0	0
		Ablabesmyia hilli	0	0	0	0	0	0	2	0	0	2	0	0

			Within Study Area						Reference sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
		Larsia ?albiceps	2	0	2	0	2	2	2	2	1	2	2	3
		Paramerina sp. 1	2	0	2	0	2	0	2	3	0	2	2	3
		Paramerina sp. 2	0	0	0	0	0	0	0	0	0	2	2	2
		Procladius sp.	1	2	2	0	3	3	3	3	1	3	0	2
	Culicidae	Culicidae sp. (P)	0	0	0	0	0	0	0	0	0	1	0	0
		Anopheles sp.	0	1	1	2	0	0	1	0	0	1	0	0
		Culex sp.	0	0	0	0	0	0	0	0	1	0	3	2
	Dolichopodidae	Dolichopodidae sp.	0	0	0	0	0	0	2	0	0	0	2	2
	Ephydridae	Ephydridae sp.	0	0	0	0	0	0	0	0	0	0	2	0
	Muscidae	Muscidae sp.	0	0	1	0	0	0	0	0	0	0	0	0
	Stratiomyidae	Stratiomyidae sp.	0	2	2	1	0	1	2	1	1	2	3	2
	Tabanidae	Tabanidae sp.	2	0	0	0	0	0	1	0	2	2	2	2
Ephemeroptera	**Baetidae**	Baetidae sp. (imm./dam.)	0	2	0	2	0	3	2	3	2	2	0	3
		Cloeon sp. (imm./dam.)	0	0	1	0	3	2	0	0	0	0	2	0
		Cloeon fluviatile	0	0	0	0	1	0	1	1	0	0	0	0
		Cloeon sp. Red Stripe	0	0	0	1	2	2	2	1	3	1	2	2
		Offadens sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	0	1
		Offadens G1 sp. WA2	0	0	0	0	0	0	2	0	1	0	0	1
		Pseudocloeon hypodelum	0	0	0	0	0	0	0	0	2	0	0	0
	Caenidae	Caenidae sp. (imm./dam.)	0	0	2	0	2	2	3	0	0	3	0	2
		Tasmanocoenis sp. (imm./dam.)	0	0	0	0	0	2	0	2	0	0	1	0
		Tasmanocoenis sp. M	0	0	0	0	0	1	0	0	0	0	0	0
		Tasmanocoenis sp. P/*arcuata*	0	3	2	2	2	0	2	3	0	2	2	3
Hemiptera	**Belostomatidae**	Belostomatidae sp. (imm./dam.)	0	0	0	0	0	0	0	0	1	0	0	0
		Diplonychus eques	2	2	0	0	2	0	0	2	0	0	3	2
	Gerridae	Gerridae sp. (imm./dam.)	1	0	0	0	0	0	2	1	0	0	0	1
		Limnogonus sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	2	3
		Limnogonus fossarum gilguy	2	2	0	0	0	0	2	0	2	0	0	0
		Limnogonus luctuosus	0	0	0	0	1	0	0	1	0	1	0	0
		Rhagadotarsus anomalus	0	0	0	0	0	0	0	0	0	0	3	3
	Hebridae	Hebridae sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	0	2
	Hydrometridae	*Hydrometra* sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	0	1
	Mesoveliidae	Mesoveliidae sp. (imm./dam.)	0	0	1	0	0	0	0	0	0	0	0	1
		Mesovelia horvathi	0	0	1	0	0	0	0	0	0	0	0	0
	Micronectidae	Micronectidae sp. (imm./dam.)	0	0	0	1	0	3	0	0	0	0	0	0
		Micronecta sp. (imm./dam./F)	0	0	1	0	0	0	0	0	0	0	0	0
	Nepidae	*Laccotrephes tristis*	0	1	0	0	1	0	0	0	0	0	1	1
		Ranatra sp. (imm./dam.)	0	0	0	0	3	1	0	0	0	0	0	0
		Ranatra diminuta	0	0	0	0	3	0	0	0	0	0	0	0
	Pleidae	*Paraplea* sp. (imm./dam.)	0	0	0	2	0	2	0	0	0	1	2	2
		Paraplea brunni	0	2	1	0	3	0	0	0	0	0	0	0
	Veliidae	Veliidae sp. (imm./dam.)	0	2	1	0	2	0	3	2	0	0	1	0

			Within Study Area						Reference sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
		Nesidovelia herberti	2	1	0	0	2	0	0	0	0	0	0	1
Lepidoptera	**Crambidae**	Acentropinae sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	2	0
		Margarosticha sp. 3	0	0	0	0	0	0	1	0	0	0	0	2
Odonata														
Zygoptera		Zygoptera sp. (imm./dam.)	0	0	0	0	3	2	2	3	0	0	2	0
	Coenagrionidae	*Argiocnemis rubescens*	0	1	0	0	2	0	2	2	0	0	0	0
		Ischnura aurora	2	0	0	2	1	0	0	0	0	0	0	0
		Ischnura heterosticta	0	0	2	0	0	0	0	0	0	0	0	0
		Pseudagrion aureofrons	0	0	0	0	1	0	0	0	2	0	0	1
	Isostictidae	*Eurysticta coolawanyah*	0	0	0	0	2	0	2	1	1	1	0	0
Anisoptera		Anisoptera sp. (imm./dam.)	2	1	2	0	3	0	2	2	0	0	1	2
	Aeshnidae	*Hemianax papuensis*	0	0	0	1	0	0	0	0	0	0	0	0
	Corduliidae	*Hemicordulia koomina*	2	0	0	2	2	2	0	0	0	2	0	0
		Hemicordulia tau	0	0	0	2	3	0	0	0	0	0	0	0
	Gomphidae	*Austrogomphus gordoni*	2	2	0	2	3	2	2	0	0	2	0	1
		Crocothemis nigrifrons	2	1	0	2	2	0	0	0	0	0	0	0
	Libellulidae	*Diplacodes* sp. (imm./dam.)	2	0	0	0	0	0	0	0	0	0	0	0
		Diplacodes haematodes	0	2	2	1	2	1	0	0	1	1	0	2
		Nannophlebia injibandi	0	0	0	0	0	0	0	0	0	0	2	0
		Orthetrum sp. (imm./dam.)	0	0	1	0	0	0	1	0	0	0	0	0
		Orthetrum caledonicum	2	1	0	2	2	1	0	0	0	2	1	2
		Orthetrum migratum	0	0	0	0	0	0	0	0	0	0	0	2
		Rhodothemis lieftincki	0	0	0	0	0	0	0	0	0	0	1	0
		Zyxomma elgneri	0	0	0	0	3	0	0	0	0	0	0	0
	Lindeniidae	*Ictinogomphus dobsoni*	0	0	0	0	2	2	0	0	0	0	0	0
Trichoptera		Trichoptera sp. (imm./dam.)	0	0	0	0	0	1	0	0	0	0	0	2
	Ecnomidae	*Ecnomus pilbarensis*	0	0	1	0	3	2	1	2	0	0	0	2
	Hydropsychidae	*Cheumatopsyche wellsae*	0	0	0	0	0	0	2	0	3	0	3	3
	Hydroptilidae	*Hellyethira* sp.	0	0	0	0	0	0	0	0	3	1	2	1
		Orthotrichia sp.	0	0	0	0	0	2	0	0	2	0	0	0
	Leptoceridae	Leptoceridae sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	0	2
		Leptocerus sp. AV2	0	0	0	0	2	2	0	0	0	0	0	0
		Oecetis sp. Pilbara 4	0	0	0	0	1	0	0	0	0	1	2	0
		Oecetis sp. Pilbara 5	0	0	0	0	0	0	2	2	0	1	0	0
		Triaenodes sp.	0	0	0	0	0	0	0	0	0	1	2	2
		Triplectides ciuskus seductus	0	2	0	0	3	0	3	0	0	3	1	2
	Philopotamidae	*Chimarra* sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	0	2
		Chimarra sp. AV17	0	0	0	0	0	0	0	0	0	0	3	1
	Polycentropodidae	*Paranyctiophylax* sp. AV5	0	0	0	0	2	0	0	0	0	0	0	0
		Taxa richness	**44**	**52**	**44**	**56**	**76**	**58**	**60**	**51**	**41**	**55**	**67**	**79**

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			Within Study Area						Reference sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
CNIDARIA														
Hydrozoa														
Anthoathecata	**Hydridae**	*Hydra* sp.	0	0	0	0	0	2	0	0	0	0	0	0
MOLLUSCA														
Gastropoda														
Hygrophila	**Lymnaeidae**	*Bullastra vinosa*	2	2	1	2	2	3	3	3	0	0	2	0
	Planorbidae	*Ferrissia petterdi*	0	1	1	1	0	0	1	2	0	0	0	**0**
		Gyraulus sp.	3	3	2	2	2	3	0	3	0	0	2	0
ANNELIDA														
Oligochaeta		Oligochaeta sp. (imm./dam.)	0	0	0	0	0	0	0	0	1	0	0	0
Tubificida	**Naididae**	Naididae sp. (imm./dam.)	0	0	0	2	2	0	0	2	0	0	0	0
		Naidinae sp. (imm./dam.)	2	2	2	0	0	0	0	0	0	0	0	0
		Allonais pectinata	0	1	0	0	0	0	0	0	0	0	0	0
		Allonais ranauana	1	2	0	2	2	0	0	0	0	0	0	0
		Nais communis	0	0	0	0	2	0	0	0	0	0	1	0
		Pristina sp. (imm./dam.)	2	2	2	2	0	0	0	2	0	0	0	0
		Pristina aequiseta	0	0	0	0	0	0	2	2	0	2	2	0
		Pristina jenkinae	0	0	0	0	0	0	0	0	0	0	1	0
		Pristina leidyi	0	2	2	3	2	2	0	3	1	0	0	0
		Pristina longiseta	3	2	2	2	0	0	3	0	0	0	1	0
		Pristina sima	1	0	0	0	0	0	0	0	0	0	0	0
	Phreodrilidae	Phreodrilidae sp.	0	0	0	0	0	0	0	0	2	0	3	3
		Antarctodrilus sp.	0	0	0	0	0	0	1	0	0	0	0	0
ARTHROPODA														
CHELICERATA														
Arachnida		Acarina sp. (imm./dam.)	0	0	1	2	2	0	2	0	1	2	1	2
Mesostigmata		Mesostigmata sp. (imm./dam.)	0	0	0	0	0	0	0	2	0	1	0	1
Sarcoptiformes		Oribatida sp.	0	0	0	0	0	0	0	0	0	0	1	0
Trombidiformes		Trombidioidea sp. (imm./dam.)	0	0	0	0	0	0	0	1	0	1	0	1
	Arrenuridae	*Arrenurus* sp.	2	1	0	0	0	2	0	0	0	0	0	0
	Aturidae	*Albia australica*	0	0	0	2	0	2	2	0	0	0	0	0
	Hydrachnidae	*Hydrachna* sp.	0	0	0	2	0	0	0	0	0	0	0	0
	Hydrodromidae	*Hydrodroma* sp.	0	0	1	2	0	1	2	1	0	0	0	0
	Hydryphantidae	*Pseudohydryphantes* sp.	0	0	2	0	0	0	0	0	0	0	0	0
	Hygrobatidae	*Australiobates* sp.	0	0	0	0	0	0	0	0	0	0	2	2
		Coaustraliobates sp.	1	0	2	2	1	1	2	0	0	1	2	0
	Limnesiidae	*Limnesia* sp. `solida group`	2	2	2	3	3	3	3	2	1	2	3	2

			Within Study Area						Reference sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
		Limnesia maceripalpis	0	0	0	2	1	2	0	0	0	0	0	0
	Limnocharidae	*Limnochares* sp. (imm./dam.)	0	0	1	0	0	0	0	0	0	0	0	0
		Limnochares australica	0	0	0	0	0	0	2	0	0	0	0	0
	Mideopsidae	*Gretacarus* sp.	0	0	0	0	0	0	2	0	0	0	0	0
	Oxidae	*Oxus* sp. (imm./dam.)	0	0	0	0	0	0	0	1	0	0	0	0
		Oxus orientalis	0	0	0	0	1	0	0	0	0	0	0	0
	Pionidae	*Piona cumberlandensis*	0	0	0	0	1	1	0	0	0	0	0	0
	Unionicolidae	*Koenikea* sp.	0	0	0	2	0	1	0	0	0	0	0	0
		Neumania sp.	0	1	0	2	2	2	0	1	0	0	1	0
		Recifella sp.	0	0	0	2	0	1	0	0	0	1	0	0
CRUSTACEA														
Malacostraca														
Amphipoda	**Paramelitidae**	Paramelitidae sp. (imm./dam.)	0	0	0	0	0	0	0	0	3	0	0	0
		Chydaekata sp. E	0	0	0	0	0	0	0	0	3	0	0	0
HEXAPODA														
Insecta														
Coleoptera		Coleoptera sp. (L) (imm./dam.)	0	0	0	0	0	0	0	0	0	2	0	0
	Carabidae	Carabidae sp. (L)	0	0	0	2	0	0	0	1	0	0	0	0
		Carabidae sp.	0	0	0	0	0	0	0	0	1	0	0	0
	Curculionidae	Curculionidae sp. (L)	0	0	0	2	0	0	0	0	0	0	0	0
		Curculionidae sp.	0	0	1	0	0	0	0	0	0	0	0	0
	Dytiscidae	*Allodessus bistrigatus*	0	1	0	1	0	0	0	0	0	0	0	0
		Bidessini sp. (L)	1	0	0	0	0	0	0	0	0	0	0	0
		Copelatus nigrolineatus	0	1	0	0	0	0	0	0	0	0	0	1
		Cybister sp.	0	0	1	1	0	0	0	0	0	0	0	0
		Cybister tripunctatus	1	1	0	0	0	2	0	0	0	0	0	0
		Hydaticus sp. (L)	0	0	0	0	0	0	0	1	0	0	0	0
		Hydroglyphus daemeli	0	0	0	0	0	0	3	0	0	0	0	0
		Hydroglyphus grammopterus	2	2	0	0	1	0	2	2	1	1	0	1
		Hydroglyphus leai	0	0	3	2	0	3	0	0	0	0	0	0
		Hydroglyphus orthogrammus	3	3	0	2	3	0	0	2	0	3	2	0
		Hydrovatus sp. (L)	2	2	0	0	1	0	0	1	0	2	0	0
		Hydrovatus opacus	2	1	0	0	1	0	0	0	0	1	0	0
		Hyphydrus elegans	0	0	0	0	1	0	0	2	0	0	0	0
		Hyphydrus lyratus	1	1	0	3	2	1	0	2	0	0	0	0
		Laccophilus sp. (L)	0	1	0	0	0	0	0	0	0	0	0	0
		Laccophilus sharpi	0	1	0	0	0	1	0	0	0	0	0	0
		Limbodessus compactus	0	0	0	1	0	1	1	2	0	0	0	0
		Limbodessus occidentalis	0	1	0	0	0	0	0	0	1	0	0	0
		Necterosoma regulare	0	1	0	0	0	0	0	1	0	1	0	0
		Neobidessodes denticulatus	0	2	0	2	0	2	2	2	0	0	0	0
		Platynectes sp. (L)	0	0	0	0	0	0	0	0	1	0	0	0

Phylum/Class/Order	Family	Lowest taxon	Within Study Area						Reference sites					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	SS	RW
		Platynectes decempunctatus var. *decempunctatus*	0	2	0	0	0	1	0	0	0	0	0	0
		Rhantaticus congestus	1	0	0	0	0	0	0	0	0	0	0	0
		Tiporus lachlani	0	0	1	0	0	0	0	0	0	0	0	0
		Tiporus tambreyi	0	0	2	0	0	0	0	0	0	2	1	2
	Elmidae	*Austrolimnius* sp. (L)	0	0	0	0	0	0	0	0	2	0	3	1
		Austrolimnius sp.	0	0	0	0	0	0	1	0	0	0	0	0
	Gyrinidae	Gyrinidae sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	2	0	0
		Dineutus australis	0	0	0	0	0	0	0	2	0	0	0	0
		Macrogyrus paradoxus	0	0	0	0	0	0	0	0	2	0	0	0
	Haliplidae	*Haliplus fortescueensis*	0	0	0	1	0	0	0	0	0	0	0	0
		Haliplus pilbaraensis	0	0	0	1	2	0	0	0	0	0	0	0
	Heteroceridae	*Heterocerus* sp.	0	0	0	0	0	2	0	0	0	0	0	0
	Hydraenidae	*Hydraena* sp.	2	2	0	2	3	2	2	3	2	3	0	0
		Limnebius sp.	0	1	0	0	2	2	2	0	0	0	0	2
		Ochthebius sp.	0	1	0	0	0	0	1	0	0	0	0	0
	Hydrochidae	*Hydrochus* sp. Group 3 'black'	0	0	0	0	0	0	2	0	0	1	0	0
		Hydrochus sp. P4	0	0	0	0	0	0	0	0	0	0	0	2
		Hydrochus eurypleuron	0	0	2	0	0	0	0	0	1	0	0	0
		Hydrochus interioris	0	0	0	2	2	0	0	0	0	0	1	0
		Hydrochus laeteviridis	0	0	0	0	0	0	0	0	0	0	0	1
		Hydrochus obscuroaeneus	0	3	0	0	0	1	1	2	0	2	0	2
	Hydrophilidae	Hydrophilidae sp. (L) (imm./dam.)	0	0	1	0	0	0	0	0	0	0	0	0
		Agraphydrus coomani	0	0	0	0	0	0	0	0	2	0	0	0
		Anacaena horni	0	2	1	0	0	0	2	0	0	1	0	0
		Berosus sp. (L)	0	2	1	0	1	0	0	0	0	0	1	1
		Berosus dallasi	0	2	0	0	0	2	0	0	0	0	3	1
		Berosus pulchellus	0	0	0	0	0	0	0	0	0	0	2	0
		Chaetarthria nigerrima (L)	0	0	0	0	0	0	0	0	0	0	0	2
		Chaetarthria nigerrima	0	0	0	0	1	0	0	0	0	0	0	0
		Enochrus sp. (L)	0	0	0	0	0	0	0	0	1	0	0	0
		Enochrus deserticola	0	2	0	0	0	0	0	0	0	0	0	0
		Helochares sp. (L)	0	2	0	0	1	0	0	0	0	0	0	0
		Helochares tatei	0	0	0	1	0	0	0	0	0	0	0	0
		Hydrophilus brevispina	0	1	0	0	0	0	0	0	0	0	0	0
		Laccobius billi	0	0	0	0	0	0	0	0	0	0	1	0
		Paracymus sp. (L)	0	1	0	2	0	0	0	1	0	0	1	0
		Paracymus spenceri	0	2	1	0	0	2	0	0	0	1	0	0
		Regimbartia attenuata	2	3	0	1	0	0	0	2	0	0	0	0
		Sternolophus sp. (L)	0	1	0	0	0	0	0	0	0	0	0	0
		Sternolophus australis	1	0	0	0	0	0	0	0	0	0	0	0
		Sternolophus marginicollis	2	2	0	0	0	0	0	0	0	0	0	1

Phylum/Class/Order	Family	Lowest taxon	Within Study Area						Reference sites					
			MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	MACREF2	MACREF1	WWS	BENS	SS	RW
	Limnichidae	Limnichidae sp. B	0	0	0	0	0	0	1	0	0	0	0	0
	Scirtidae	Scirtidae sp. (L)	0	2	0	0	0	1	3	2	3	2	1	0
	Staphylinidae	Staphylinidae sp.	0	0	0	0	0	1	0	0	0	1	0	0
Diptera	**Cecidomyiidae**	Cecidomyiidae sp.	0	0	0	0	0	0	2	0	0	2	0	0
	Ceratopogonidae	Ceratopogonidae sp. (P)	1	0	0	1	0	0	0	2	1	0	1	0
		Ceratopogoninae sp.	3	3	2	3	2	0	3	3	3	3	3	1
		Dasyhelea sp.	3	3	2	3	3	0	0	2	2	2	2	2
		Forcipomyiinae sp.	0	0	0	2	0	0	0	2	0	0	0	1
	Chironomidae	Chironomidae sp. (P)	0	0	1	2	0	2	3	2	3	1	2	0
	Chironominae													
	Chironomini	Chironomini sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	2	0
		Chironomus aff. *alternans*	2	3	0	0	1	0	0	0	0	0	0	0
		Cladopelma curtivalva	0	0	0	0	0	2	2	0	0	0	0	0
		Cryptochironomus griseidorsum	0	0	0	0	0	0	2	0	2	0	2	0
		Dicrotendipes jobetus	0	0	0	0	2	0	0	0	0	0	0	0
		Dicrotendipes sp. \`CA1\`	0	0	2	3	2	3	0	0	2	0	1	2
		Dicrotendipes sp. P4	0	2	0	0	1	0	0	0	3	0	2	2
		Kiefferulus intertinctus	0	0	0	0	0	0	0	3	0	2	0	0
		Paracladopelma sp.	0	0	1	0	0	0	0	0	0	0	0	0
		Paracladopelma sp. K2	0	0	0	0	0	0	0	0	2	0	0	3
		Paracladopelma sp. M1	0	0	0	0	0	0	2	0	0	0	0	0
		Polypedilum (*Pentapedilum*) *leei*	0	0	0	0	0	0	0	3	0	0	0	0
		Polypedilum sp.	0	0	0	0	0	0	0	0	0	2	2	0
		Polypedilum sp. K1	0	0	0	0	0	0	3	0	0	0	0	0
		Polypedilum watsoni	0	0	0	0	0	0	0	0	0	2	0	0
		Skusella subvittata	0	0	0	0	0	0	2	0	0	0	0	0
		Stenochironomus watsoni	0	2	0	0	1	0	0	2	0	0	0	0
	Tanytarsini	*Cladotanytarsus* sp.	0	0	0	0	1	0	0	0	0	0	0	0
		Paratanytarsus sp.	2	0	2	2	2	2	0	0	0	0	0	3
		Rheotanytarsus sp.	0	0	0	0	0	0	0	0	2	1	0	0
		Tanytarsus sp.	2	3	0	0	2	3	3	3	2	2	3	2
	Orthocladiinae	*Corynoneura* sp.	0	0	0	0	0	0	2	0	1	0	2	1
		Cricotopus albitarsis	0	0	0	0	0	0	0	0	3	0	0	3
		Nanocladius sp.	0	0	0	0	0	2	0	0	0	0	0	0
		nr. *Gymnometriocnemus* sp.	0	0	0	0	0	0	0	0	0	0	2	0
		Parametriocnemus sp.	0	0	0	0	0	0	2	0	0	0	0	0
		Rheocricotopus sp.	0	0	0	0	0	0	0	0	0	0	3	0
		Thienemanniella sp.	0	0	0	0	0	0	2	0	3	0	2	2
	Tanypodinae	*Ablabesmyia hilli*	0	1	0	0	1	2	0	3	0	2	0	0
		Ablabesmyia notabilis	0	0	0	0	0	0	0	0	0	0	2	0
		Clinotanypus crux	0	0	0	0	1	0	0	0	0	0	0	0
		Larsia ?albiceps	3	3	3	3	3	3	3	3	1	2	2	3

Phylum/Class/Order	Family	Lowest taxon	Within Study Area MarC1	MarC2	MarC3	MarC4	MarC5	MarC6	Reference sites MACREF2	MACREF1	WWS	BENS	SS	RW
		Paramerina sp. 1	2	2	0	0	2	2	0	3	3	3	2	3
		Paramerina sp. 2	0	0	0	0	0	0	0	0	0	2	0	0
		Procladius sp.	1	2	2	0	2	2	3	0	0	2	3	0
		Thienemannimyia sp.	0	0	0	0	0	0	3	0	0	0	0	0
	Culicidae	Culicidae sp. (P)	0	0	2	0	0	0	0	0	0	0	0	0
		Anopheles sp.	0	0	2	1	1	1	0	0	2	0	0	0
		Culex sp.	0	2	0	0	0	0	0	2	0	0	0	0
	Dolichopodidae	Dolichopodidae sp.	0	2	0	0	0	0	0	1	2	0	3	0
	Psychodidae	Psychodidae sp.	0	0	0	0	0	0	0	1	0	1	0	0
	Sciomyzidae	Sciomyzidae sp.	0	2	0	0	0	0	0	0	0	0	0	0
	Simuliidae	Simuliidae sp.	0	0	2	0	0	0	2	0	0	0	3	0
	Stratiomyidae	Stratiomyidae sp. (P)	0	0	0	0	0	0	1	0	0	0	0	0
		Stratiomyidae sp.	2	2	2	1	2	0	0	2	2	2	2	0
	Tabanidae	Tabanidae sp.	1	3	2	1	2	0	0	2	0	0	0	0
	Tipulidae	Tipulidae sp.	0	1	1	0	0	0	0	1	0	0	2	0
Ephemeroptera	**Baetidae**	Baetidae sp. (imm./dam.)	2	2	3	3	2	3	3	3	3	3	3	3
		Cloeon sp. (imm./dam.)	2	2	0	0	0	0	0	0	0	0	0	0
		Cloeon fluviatile	0	0	2	0	0	0	0	0	0	2	0	0
		Cloeon sp. Red Stripe	3	3	3	3	3	2	2	2	0	1	1	2
		Offadens sp. (imm./dam.)	0	1	0	0	0	0	0	0	0	0	2	0
		Offadens G1 sp. WA2	0	0	0	0	0	0	2	0	0	0	0	0
		Offadens soror	0	0	0	0	0	0	0	0	0	0	1	0
		Pseudocloeon hypodelum	0	0	0	0	0	0	0	0	3	0	0	2
	Caenidae	Caenidae sp. (imm./dam.)	0	0	2	2	0	0	3	0	0	3	3	3
		Tasmanocoenis sp. (imm./dam.)	2	3	0	0	2	3	0	2	0	0	0	0
		Tasmanocoenis sp. M	0	0	0	0	0	0	0	0	0	0	2	2
		Tasmanocoenis sp. P/*arcuata*	1	3	2	2	2	3	3	1	3	3	2	3
Hemiptera	**Belostomatidae**	*Diplonychus eques*	2	2	0	0	0	0	0	2	0	0	2	0
	Gerridae	Gerridae sp. (imm./dam.)	3	0	3	0	0	0	0	2	2	0	0	0
		Limnogonus sp. (imm./dam.)	0	0	0	1	0	0	2	0	0	0	0	0
		Limnogonus fossarum gilguy	0	0	0	0	4	0	0	1	0	0	1	1
		Limnogonus luctuosus	0	0	0	0	0	0	0	0	0	2	0	0
	Hebridae	*Hebrus axillaris*	0	0	0	0	0	1	0	0	0	0	0	0
	Mesoveliidae	Mesoveliidae sp. (imm./dam.)	0	0	0	0	2	0	0	0	0	0	0	0
		Mesovelia vittigera	0	0	0	0	0	0	1	0	0	0	0	0
Corixoidea		Corixoidea sp. (imm./dam.)	0	0	0	2	0	2	0	0	0	1	0	0
	Micronectidae	*Micronecta* sp.	0	0	0	0	0	0	0	1	0	0	0	0
		Austronecta micra	0	0	0	0	0	1	0	0	0	0	0	0
		Micronecta annae	0	0	0	0	0	0	0	0	0	1	0	0
	Nepidae	*Laccotrephes tristis*	0	0	0	0	0	1	0	0	0	0	0	0
	Notonectidae	*Anisops* sp. (imm./dam./F)	0	0	0	0	0	0	0	2	0	0	0	0
		Anisops nabillus	0	0	0	0	0	0	0	1	0	0	0	0

			Within Study Area						Reference sites					
Phylum/Class/Order	**Family**	**Lowest taxon**	**MarC1**	**MarC2**	**MarC3**	**MarC4**	**MarC5**	**MarC6**	**MACREF2**	**MACREF1**	**WWS**	**BENS**	**SS**	**RW**
	Pleidae	*Paraplea* sp. (imm./dam.)	1	2	0	2	2	0	2	0	0	1	0	0
		Paraplea brunni	2	2	2	2	2	0	0	0	0	0	0	0
	Veliidae	Veliidae sp. (imm./dam.)	0	2	0	0	1	0	3	1	1	0	0	0
		Microvelia sp. (imm./dam.)	0	0	2	0	0	0	0	0	0	1	0	0
		Nesidovelia herberti	0	0	0	0	0	0	0	0	0	0	1	0
		Nesidovelia peramoena	0	0	0	0	0	0	1	0	0	0	0	0
Lepidoptera	**Crambidae**	Acentropinae sp. (imm./dam.)	0	2	0	0	0	0	2	0	3	0	2	0
Odonata														
Zygoptera		Zygoptera sp. (imm./dam.)	2	2	2	3	0	2	2	2	0	3	2	2
	Coenagrionidae	*Argiocnemis rubescens*	1	2	1	0	0	0	2	0	1	1	2	0
		Ischnura aurora	0	0	2	1	0	2	0	0	0	0	0	0
		Pseudagrion aureofrons	0	0	0	0	0	1	0	0	0	0	0	0
	Isostictidae	*Eurysticta coolawanyah*	0	0	0	0	0	0	2	0	0	0	1	0
Anisoptera		*Anisoptera* sp. (imm./dam.)	2	2	2	0	2	2	3	2	3	2	2	0
	Aeshnidae	Aeshnidae sp. (imm./dam.)	0	0	0	0	0	2	0	0	0	0	0	0
		Adversaeschna brevistyla	0	0	0	0	0	0	0	1	0	0	0	0
		Hemianax papuensis	0	1	0	0	0	0	0	2	0	0	0	0
	Corduliidae	*Hemicordulia koomina*	0	0	0	0	0	2	0	0	0	0	0	0
		Hemicordulia tau	0	0	0	0	0	0	0	1	0	0	0	0
	Gomphidae	*Austrogomphus gordoni*	0	0	0	0	0	2	2	0	0	0	0	0
	Libellulidae	*Diplacodes haematodes*	1	2	1	0	0	2	0	0	0	2	0	0
		Orthetrum caledonicum	0	2	1	0	0	2	0	0	0	0	0	0
		Zyxomma elgneri	0	0	0	0	0	1	0	0	0	0	0	0
	Lindeniidae	*Ictinogomphus dobsoni*	0	0	0	0	2	2	0	0	0	1	0	0
Trichoptera	**Ecnomidae**	*Ecnomus pilbarensis*	0	2	0	2	2	2	2	2	0	0	2	2
	Hydropsychidae	*Cheumatopsyche* sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	3	0
		Cheumatopsyche wellsae	0	0	0	0	0	0	3	0	3	0	4	2
	Hydroptilidae	*Hellyethira* sp.	0	0	0	0	0	0	0	0	2	0	0	0
		Orthotrichia sp.	0	0	0	1	2	3	0	0	0	0	2	0
	Leptoceridae	Leptoceridae sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	2	0
		Oecetis sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	1	0
		Oecetis sp. Pilbara 4	0	2	0	0	0	2	1	0	0	1	1	0
		Oecetis sp. Pilbara 5	0	0	0	0	0	2	0	0	0	0	0	0
		Triaenodes sp.	0	0	0	0	0	0	0	0	0	1	0	1
		Triplectides sp. (imm./dam.)	0	0	0	0	0	1	0	0	0	3	2	2
		Triplectides ciuskus seductus	0	2	0	0	0	1	4	0	0	0	3	0
	Philopotamidae	*Chimarra* sp. (imm./dam.)	0	0	0	0	0	0	0	0	0	0	2	1
		Chimarra sp. AV17	0	0	0	0	0	0	3	0	2	1	3	2
	Polycentropodidae	*Paranyctiophylax* sp. AV5	0	0	0	0	0	0	2	0	0	0	0	0
		Taxa richness	**46**	**78**	**51**	**57**	**57**	**65**	**64**	**64**	**47**	**57**	**71**	**45**